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FINAL REPORT

AN EXPLORATORY STUDY OF INDIVIDUAL INFORMATION-PROCESSING AND DECISION-MAKING

NASA CONTRACT NSR 15-003-055

Project #11

by

David W. Cravens

August 15, 1967

Aerospace Research Applications Center
Indiana University Foundation
Bloomington, Indiana

FOREWORD

This is the final report for Project #8 of NASA Contract NSR 15-003-055. The style of this report is in a format as required for a Doctor of Business Administration thesis by the Graduate School of Business at Indiana University.

AN EXPLORATORY STUDY OF INDIVIDUAL INFORMATION-PROCESSING AND DECISION-MAKING

BY

DAVID W. CRAVENS

A Dissertation Submitted in Partial Fulfillment of
the Requirements for the Degree of Doctor of
Business Administration in the Graduate
School of Business of Indiana University

INDIANA UNIVERSITY
GRADUATE SCHOOL OF BUSINESS

1967

Partial support for this study was provided by the National Aeronautics and Space Administration under contract NSr-15-003-055 to the Aerospace Research Applications Center, Indiana University Foundation.

ACCEPTANCE

This dissertation has been accepted in partial fulfillment of the requirements for the Degree of Doctor of Business Administration in the Graduate School of Business of Indiana University.

Date July 6, 1967

W George Pinnell

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Chairman

Member

Member

PREFACE

Research efforts are seldom the exclusive product of the principal investigator. This study is certainly no exception. In the process of development of the study from its initial conception to completion, numerous debts of assistance were incurred which deserve acknowledgment. In the first place, I am grateful for the many contributions of my Chairman, Dr. William G. Panschar. His efforts in helping me to develop the dimensions of the study during its initial stages were all important in arriving at a suitable dissertation topic. During the later stages of the study he provided useful conceptual insights along with continuous encouragement so necessary in moving the study through to completion. His suggestions on organization of the dissertation were invaluable.

I also want to acknowledge the many insights, contributions, and encouragements provided by the other members of my dissertation committee, Dr. Howard L. Timms and Dr. Robert F. Kelly. Dr. Timms was particularly responsible for providing important insights into the scientific and technical environment of the study as well as the conceptual schemes and ideas employed in the study. Dr. Kelly provided numerous insights and suggestions concerning the methodology employed. In particular, his suggestions concerning variable measurement and analysis of data were important inputs to the study.

There are many others to whom a note of appreciation is due. Dr. Larry L. Cummings provided helpful suggestions concerning the measurement of study variables. Mr. Richard W. Counts was of major assistance in helping me to utilize an existing computer program for data analysis.

I am indebted to the Technology Utilization Division of the National Aeronautics and Space Administration for partial support of the research under contract NSR-15-003-055. I want to express my appreciation to the Aerospace Research Applications Center for providing the research site of the study. A special note of thanks is due to Dr. Arthur M. Weimer and the management and staff of ARAC for the resources and cooperation made available to me during the study.

I would like to express my appreciation to both Mrs. Libby Rader and Mrs. Irene Devins for their patience and diligence in typing drafts as well as for numerous improvements in the appearance of the manuscript from rough to final copy. Special thanks are due to Mrs. Devins for her helpful editorial comments and for her assistance in data collection and analysis.

Finally, I want to thank my wife, Sue, not only for her typing and editorial assistance on the dissertation, but also for her patience, encouragement, and understanding during the study. A special thank you is due to my daughter, Karen, for her own special kind of encouragement.

D.W.C.

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ABSTRACT

The unprecedented growth of information in recent years has precipitated extensive research. The bulk of this work has been centered on information systems which have been conceived, developed, and implemented to cope with the problems associated with the information "explosion." This study fits into the broad area of research on information-processing and decision-making.

The individual user of information is a vital element in any information system, formal or informal. The impetus for this study emerged from an apparent neglect, or, at best, superficial understanding of the individual's information-processing behavior in the context of problem solving.

The overall objective of the study is an exploratory investigation of the possible correlates of individual information-processing which takes place in solving technical tasks associated with research and development projects and programs. More specifically, the effort is intended to seek out the apparently important variables relating to information-processing, the individual, and the task within a given environment; link these variables into a conceptual analytical structure; and then investigate the existence of relationships among the variables via a field study.

The study consists of four separate, but interrelated phases. The first concerns the identification and evaluation of applicable research foundations. The three mainstreams of research drawn from are the decision-making process, individual thinking processes, and information processing.

The second phase involves the development of a conceptual system of variables for use in identifying potential relationships and investigating them empirically. Variables are identified from the domains of the individual, task, and individual/task interaction which appear promising as potential correlates of information-processing. A second set of variables is identified within the information-processing phases of search, evaluation, and integration of information into the decision.

The third phase deals with the specific methodology utilized in the study. The Aerospace Research Applications Center at Indiana University provides a research site which offers the many advantages of a quasi-controlled laboratory experiment and yet seems to overcome many of the limitations inherent in studies utilizing college students.

The final phase concerns the analysis of the empirical data of the study utilizing canonical analysis and a discussion of the results obtained in the study.

The results of the research are quite encouraging. The conceptual system of variables appears to be highly associated, with certain variables playing more important roles in the system than others. In particular, an individual's information-processing efficiency, his image state (state of knowledge) for a particular task, his risk-taking propensity, and the result rating of the task (in terms of meeting specified objectives and constraints) appear to impinge rather significantly upon the set of variables in the information-processing domain. These variables represent the individual, task, and interaction domains. Those from the individual domain seem to be the stronger correlates of information-processing.

Thus, the objectives of the exploratory study were accomplished in that certain apparently important variables relating to information-processing, the individual, and the task (within the given environment) were identified, and the existence of inter-relationships indicated between the independent and dependent variable sets.

The results of the study are not operational in that they can be moved intact to some immediate area of application. Rather, they provide a group of findings that can form a base for further research and development. The current state of knowledge on individual information-processing is limited and, at best, this study provides a modest insight into an extremely complex area. The need for further research is apparent.

CHAPTER 1

INTRODUCTION

The main thrust of the research discussed in this and the following chapters is an exploratory investigation of individual information-processing and decision-making. In this introductory chapter the study is linked to the rest of the world in a sequence beginning with an examination of the role of information in our technological society. A brief look is taken at the phenomenon which has been called the "information explosion." The problem areas which provide the impetus for the present study are discussed. The approach which was taken to gain insights into these problem areas is outlined. Finally, the organization of the investigation is discussed in the sequence of the remaining chapters.

NATURE OF THE PROBLEM

Information and Our Society

Our modern technological society is based upon information. Information is the cornerstone of our world.[1] Information in this context is closely linked to knowledge as Machlup indicates:

> "Linguistically, the difference between knowledge and information lies chiefly in the verb form: to *inform* is an activity by which knowledge is conveyed; to *know* may be the result of

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[1]Charles R. DeCarlo, "Perspectives on Technology," *Technology and Social Change*, ed. Eli Ginzberg (New York: Columbia University Press, 1964), p. 13.

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> having been informed. 'Information' as the act of informing is designed to produce a state of knowing in someone's mind. 'Information' as that which is being communicated becomes identical with 'knowledge' in the sense of that which is known. Thus, the difference lies not in the nouns when they refer to *what* one knows or is informed about; it lies in the nouns only when they are to refer to the *act* of informing and the *state* of knowing, respectively. It happens that information is not often used in the latter sense."[2]

The generation, communication, and application of knowledge, in the dynamic sense that Machlup uses to define it, refers to information as knowledge; but some may argue that information, in the broadest sense, forms only a vital part of knowledge.[3] However, in either sense the key role of information in our society seems clear.

The so called "information explosion" provides the next point of reference in linking this study with related research. The nation's store of scientific and technical information is growing at an exponential rate. A shortage of scientists and engineers exists in many fields. Expenditures for research and development (R & D) have grown from less than $5 billion in the early 1950's to an estimated $23 billion in 1966.[4] This reservoir of technology represents a significant potential if R & D results can be transferred into applications other than those for which the work was originally intended. The complexities of modern technology

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[2]Fritz Machlup, *The Production and Distribution of Knowledge in the United States* (Princeton, N. J.: Princeton University Press, 1962), p. 15.

[3]For example, see Rowena W. Swanson, *Information System Networks--Let's Profit from What We Know*, AFOSR 66-0873 (Arlington, Va.: U.S. Air Force, Office of Aerospace Research, June, 1966), p. 1. She suggests that knowledge is produced through the use of information but does not want to equate the two.

[4]Victor J. Danilov, "1966 I-R Forecast: $23-billion for Research," *Industrial Research* (January, 1966), p. 32.

increase the possibility of duplicative efforts. The information "explosion" in science and technology is indicative of a similar trend in virtually all fields.

Dr. Harold Wooster of the United States Air Force has made an interesting (and somewhat frightening) observation on the potential dangers of the information growth curve by indicating that "the curve bears a striking similarity to the first half of the growth curve for a bacterial colony--before it starts poisoning itself with its own waste products."[5] Murray has captured the spirit of the problems of the exponential growth of information in the following:

> "In order to emphasize the problem, it is worthwhile to cite some figures. The rate at which technical documents are produced at the present time is estimated to be well over 500,000 per year. In every 24-hour period approximately 20,000,000 words of technical information are being recorded. A reader capable of reading 1,000 words per minute would require $1\frac{1}{2}$ months, reading 8 hours every day, to get through 1 day's technical output, and at the end of that period, he would have fallen $5\frac{1}{2}$ years behind in his reading! Even in attempting to read the portion of the literature in a single subject field such as chemistry, he would find himself falling behind an estimated 850,000 pages per year. This production rate of scientific information will undoubtedly increase as countries such as China and India begin to produce technical work commensurate with their size."[6]

The critical problems brought about in recent years by the information explosion have not been neglected. On the contrary, these areas of concern have precipitated extensive research along with the emergence

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[5]William S. Beller, "National Information Program Impends," *Missiles and Rockets* (November 1, 1965), p. 18.

[6]Hubert J. Murray, Jr., *Methods for Satisfying the Needs of the Scientist and the Engineer for Scientific and Technical Information*, Report No. RSIC-510 (Redstone Arsenal, Ala.: Redstone Scientific Information Center, January, 1966), p. 1.

of a new discipline known as "information science." Research as well as applicational efforts are being carried on by the federal government, the information industry, universities, and research institutes. For example, the National Science Foundation estimates that over $354 million was spent in Fiscal Year 1966 by the federal government for the collection of general-purpose technical information.[7]

Information Systems

Information systems have been conceived, developed, and implemented to cope with the problems of information growth. Information systems are the result of the application of information science principles and concepts. Borko defines an information system as a collection of recorded information, custodians who organize and maintain the collection, a procedure for retrieving the information, and the users who utilize the information base to satisfy a variety of needs.[8]

The problems of storing, handling, retrieving, and using information are currently gaining widespread attention by governmental agencies, computer manufacturers, individual firms and others. A major portion of the research on information has been directed toward the formulation and design of formal information systems. Various systems have been developed

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[7]Richard L. Lesher and George J. Howick, *Background, Guidelines, and Recommendations for Use in Assessing Effective Means of Channeling New Technologies in Promising Directions*. Report prepared for the National Commission on Technology, Automation, and Economic Progress (Washington, D.C.: National Aeronautics and Space Administration, November, 1965), p. A-14.

[8]H. Borko, *The Conceptual Foundations of Information Systems*, SP-2057 (Santa Monica, Calif.: System Development Corporation, May 6, 1965), p. 5.

to cope with the range of problems involved in processing information. Extensive research has been accomplished on information indexing systems, computerized retrieval of information, automated processing of information, and related areas.[9]

A vital element in any information system (formal or informal) is the individual user of information. The ultimate purpose of an information system is to effectively link the user with the appropriate base of information in such a way that information needs can be matched with relevant information. Information use in the context of the present study is related to problem solving efforts in contrast to information for the purpose of extending an individual's general store of knowledge.

While the individual user of information has been the subject of several research efforts, a relatively small body of knowledge has been developed relative to the task-oriented information-processing activities of individual technical people in terms of the influences on what information is sought, what the problem solver does with the information, and the relationship of this information to the results achieved by the problem solver.

Technical problem solving can be viewed as a processing system through which information inputs are transformed into new information. In this context the individual scientist or engineer is an information processor. He obtains, evaluates, utilizes, transforms, and generates

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[9]Lawrence Berul, *Information Storage and Retrieval, A State of the Art Report*, PR 7500-145 (Philadelphia: Auerbach Corporation, September 14, 1964).

information.[10] Individual information-processing in this context provides the specific focus of this research.

Questions of Interest

The questions of direct interest in the study are those relating to the individual user of information in his role as a decision maker or problem solver. If a better understanding is to be gained concerning the information-processing activities of the individual problem solver, answers to the following questions are needed: What characteristics of the individual and the task influence his information-processing behavior? What are the important elements of individual information-processing? Can the complexities of the individual, the task, and his resulting information-processing activities be abstracted into a conceptual model which will be useful in describing individual information-processing? What are the important variables involved in the process and how are they related?

A detailed investigation of these questions, such that inferences across a large population might be made, would require a large-scale program of research. Such an effort is in excess of the time and financial constraints of this investigation. In view of this constraint the strategy selected was that of conducting an exploratory study aimed at identifying variables and uncovering promising avenues which might provide foundations for more precise evaluation in follow-on research efforts.

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[10] Auerbach Corporation, Interview Guide Handbook (Philadelphia: Auerbach Corporation, July 2, 1964), p. 3.

STUDY OBJECTIVES

Purpose

The concern of this study was not with arriving at the best, most rational way of processing information by the individual. Rather, the intent of the research was to gain insights, and hopefully some new concepts, which would help to describe how the individual does, in fact, process information. The study represents an attempt to look at information-processing from the point of view of the individual user of information in the context of his problem solving efforts. The effort was directed toward gaining a better understanding of the information-processing characteristics of individual technical people rather than devising ways of improving the process.

The objective of the investigation was to conduct an exploratory study on the information-processing behavior of individuals during the process of solving technical tasks or problems. In particular the research sought to identify information-processing variables in the phases of search, receipt, evaluation, and integration of information during the process of solving technical tasks associated with research and development projects and programs. The existence of problems requiring solutions was taken as given. The task span of interest ranged from the identification of a task through time to the completion of the task. The study involved a process (over time) viewpoint of individual information-processing.

The intent of the research was to build upon existing concepts and research foundations as well as to develop new insights into individual information-processing in a scientific and technical research and development environment. Specifically the effort was concentrated on:

1. Identifying certain potentially important variables relating to information-processing, the individual, and the task within a given environment.

2. Developing a conceptual analytical structure linking information-processing characteristics to those characteristics pertaining to the individual and the task.

3. Formulating and investigating via an empirical study, the existence of interrelationships among dependent information-processing variables and independent individual and task variables.

Study Applications

The results of this study could contribute to further research in a number of areas. Several of the more important potential applications are indicated below.

Considering the apparent linkage between information-processing and decision-making, a better understanding of individual information-processing could contribute useful findings to the broad body of research on decision-making.

In order to design an improved information system it is important to understand how an existing informal system operates. A better knowledge of how individual engineers and scientists process scientific and technical information in solving problems should provide helpful insights into improving the process.

If the premise is accepted that most firms, particularly small ones, currently are not fully utilizing potentially valuable and relevant technology generated external to the firm, then the research discussed in the following chapters should help contribute to findings which will improve the transfer of technology to industrial firms. Reference is made here both to action external to the firm (for example, at the policy level of the Federal Government) and within the firm.

Relatively little research has been directed toward how the user actually processes scientific and technical information. The most significant work is probably the Auerbach Study.[11] Certainly, there is an indicated need for additional research concerning the ultimate processor of scientific and technical information.

Extensive scientific and technical information efforts are under way outside the Federal Government. Examples include the Engineer's Joint Council, American Petroleum Institute, Rubber Institute, American Chemical Society, American Society for Metals, and numerous specialized information efforts throughout the country. The research should be applicable to the work underway by these groups.

The conceptual framework developed in Chapter 3 should be useful to other researchers contemplating research on the information-processing behavior of individuals in their problem solving efforts. The availability of a conceptual framework should aid others in analyzing the individual's information-processing system and in formulating hypotheses for testing. The work should contribute to better understanding of the role of information in decision-making, particularly the technical decision process.

A final area of interest is that of providing guiding principles for curriculum development on information science and technology in

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[11] _Ibid_.

university science and engineering programs. This problem is emphasized in the Report of the President's Science Advisory Committee:

> "Familiarity with modern techniques of information processing is necessary for the modern scientist and engineer. Our colleges and universities must provide instruction in these techniques as part of the regular scientific curriculum. They must also educate in the art of handling information more professionals who can lighten the burden of the technical man and can invent new techniques of information retrieval."[12]

It is not intended, or even suggested, that this research effort will provide a major input to each of the areas outlined above. Rather, the intent is to link the present study to areas where the findings may be potentially useful. The exploratory nature of the present study limits its direct application to a number of these areas. However, the findings should provide elements of knowledge which can be integrated and developed further in future studies.

APPROACH TO THE PROBLEM

The study reflects a systematic approach to the investigation of the association between certain individual, task, and joint variables and individual information-processing variables. In terms of Rigby's distinction between research directed toward <u>reporting</u>, <u>description</u> and <u>explanation</u> this study is clearly descriptive in nature.[13] It attempts to give an accurate account of the series of events which take place as

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[12] The President's Science Advisory Committee, <u>Science, Government, and Information</u> (Washington, D.C.: U. S. Government Printing Office, January 10, 1963), p. 2.

[13] Paul H. Rigby, <u>Conceptual Foundations of Business Research</u> (New York: John Wiley and Sons, Inc., 1965), p. 6.

well as to describe the specific events. There is no intent to generalize to a larger population from the empirical observations made.

The investigation is approached by building on existing research coupled with the insights of the researcher. The study moves from an identification and analysis of previous research to the development of a conceptual system of variables for empirical investigation. The specific stages of the research effort are outlined below.

Previous research was sought out in the areas of human thinking processes, decision-making, and information-processing in an attempt to identify findings applicable to the study as well as to suggest new avenues of inquiry.

Next a conceptual model or system of variables was developed by building upon previous research, where applicable. New insights were integrated, where they seemed appropriate. The resulting variables system consisted of a set of independent variables relating to the individual, the task, and the interaction of individual/task. . . and a set of dependent information-processing variables relating to the search, receipt, evaluation, and integration of information with respect to a task facing an individual.

The conceptual model provides a frame of reference for identifying the relationships of interest. These relationships concern the total impact of the independent variable group on the dependent variable group as well as the individual role of each variable in the system.

The scientists and engineers of the Aerospace Research Applications Center at Indiana University were the subjects utilized to empirically investigate the relationships of interest. A multivariate technique called Canonical analysis was used to analyze the data.

The approach was to examine possible relationships rather than to attempt to establish them. The intent was to develop a basis for more extensive research by identifying a group of potentially significant variables making up the conceptual system of variables.

ORGANIZATION OF THE STUDY

Chapter 2 is concerned with identifying and examining the research foundations applicable to the study. These foundations cut across several disciplines. In order to guide the identification of related research certain critical dimensions of the present study are identified within which applicable research foundations can be examined. These are the _decision-making process_, _individual thinking processes_, and _information-processing_.

The conceptual framework for analysis is developed in Chapter 3 building, where appropriate, upon previous work. A system of variables is constructed, made up, on the one hand, of a selected group of independent variables pertaining to the individual, the task, and the interaction of task and individual, and on the other hand by a set of dependent information-processing variables. The independent variables are considered as likely candidates for possible correlates of the dependent information-processing variables.

The variable system of Chapter 3 provides the frame of reference for identifying the relationships of interest in the study and for guiding the empirical investigation of these relationships.

In Chapter 4 the research methodology of the study is presented. The field study and statistical techniques used to examine empirically the relationships of interest are discussed. The tasks and subjects of the study are identified as well as the instruments used to collect empirical data.

The results of the multivariate statistical analysis of the data are presented and examined in Chapter 5. The analysis includes the <u>number</u> of ways the two variable sets are related as well as the <u>strengths</u> and <u>nature</u> of the identified relationships.

Chapter 6 concludes the study by indicating a summary statement of the results of the investigation. Certain implications of the study are presented. The chapter is concluded by the identification of some directions for future research.

CHAPTER 2

RESEARCH FOUNDATIONS

INTRODUCTION

The purpose of this chapter is to identify and examine areas of research related to the present study. There are a variety of perspectives which may be utilized for studying decision processes. Each reflects the unique elements of the researcher's focus. In this study interest centers on individual information-processing characteristics and those individual and/or task characteristics influencing the processing of information relative to a given task. The study utilizes this unique point of view in the context of a decision process ranging from recognition of a problem to the solution of the problem or task. The focus is on the individual rather than a group. The relationship between decision-making and individual information-processing is that the decision-making process provides a frame of reference within which to look at information-processing. Thus, the concern is *not with how an individual makes a decision* but rather with *how he processes information during a decision process* leading to a final choice.

Careful identification of research applicable to this study is both important and difficult in terms of the exploratory nature of the effort. The foundations of study cut across several disciplines. The dividing line between past research which is applicable to the study and that which is not is by no means clear cut. The body of research on decision-making is voluminous. Psychologists have long been concerned with human thinking processes.[1] It is necessary to select carefully from this vast literature in the interest of considering only directly relevant research.

Applicable research foundations serve as guidelines and building blocks for developing the Conceptual Analytical Structure for the study which is presented in Chapter 3.

The plan of the chapter is first to develop a set of dimensions of the study within which applicable research foundations can be examined. Next, these dimensions of related research are examined. Finally, a critical resume' of related research is presented in the interest of highlighting the nature of the applicable findings as well as pointing out the limitations of previous work with respect to this study.

It is desirable to establish certain broad dimensions of the study which can be utilized as a framework within which related research can be identified and examined. These dimensions are indicated in Figure 1. They are the <u>individual</u>, the <u>decision</u> or task, and <u>information-processing</u> with respect to the task. These elements are viewed in terms of a decision process within a given environment.

Within these dimensions certain specific interests can be identified with reference to this study. The identification of study variables provides one specific focus. Conceptual guidelines are of particular interest. Ideas for possible conceptual linkages of the study dimensions are relevant. Measuring instruments which may be potentially useful with respect to study variables are also relevant.

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[1]Orville G. Brim Jr., <u>et al</u>., <u>Personality and Decision Processes</u> (Stanford, Calif.: Stanford University Press, 1962), p. 9.

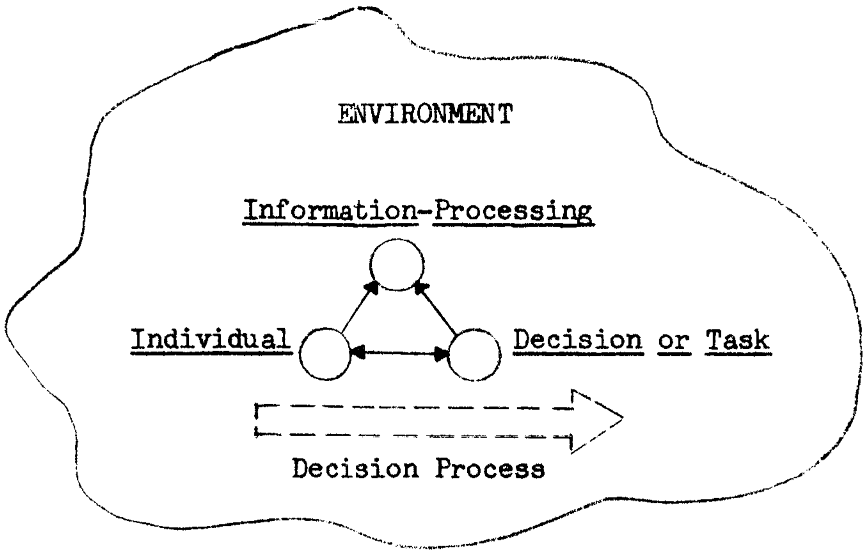

Figure 1 -- Study Dimensions

DECISION-MAKING PROCESS

The body of knowledge concerning decision-making offers an important source of research findings applicable to this research effort. The literature on decision-making is extensive. No attempt will be made to discuss the broad base of research which has been accomplished. Research with the viewpoint of decision-making or problem solving as a multi-stage process is of primary importance. The ultimate objective of looking at this research area is to gain insights as to the information-processing aspects of the decision-making process. In particular, interest centers on (1) conceptualization of a decision process and (2) classifications, levels, or types of decisions with particular emphasis on important variables in the decision process.

Conceptualization of a Decision Process

Simon indicates that decision-making in terms of an analytical concentration on the final outcome ignores the total, lengthy, complex process of altering, exploring, and analyzing that which precedes the final moment.[2] Conceiving of a decision in terms of a process allows the decision to be examined via multi-stage elements rather than to consider only the outcome.

Brim, et al. conducted an exploratory study concerning the relationship between the decision process and personality and social structure.[3] They utilized 200 subjects and examined 50 variables focusing on the decision process phases of evaluation of alternatives and strategy selection. Ten descriptive variables were used at each stage to relate decision process variables (dependent) to personality and social structure variables (independent). The study, although process oriented, involved observations at one point in time. While each discipline has its own unique prospective for studying decision-processes, the Brim et al. research provides a wealth of guidelines potentially useful with respect to decision-process variables, relationships, and methodology.

The concept of viewing a decision situation in terms of a process rather than the outcome is not new.[4] Simon characterizes the decision-making process as: (1) searching the environment for conditions calling

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[2]Herbert Simon, The New Science of Management Decision (New York: Harper & Brothers Publishers, 1960), p. 1.

[3]Brim, et al., op. cit.

[4]For example, Richard M. Cyert and James G. March in A Behavioral Theory of the Firm (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963), have formulated a decision process framework based on empirical studies of decision-making within the firm. William J. Gore in Administrative Decision-Making: A Heuristic Model (New York: John Wiley & Sons, Inc., 1964), views the decision-making process as a flow through a series of layers of organization and has identified the phases of perception, evaluation set, estimation of consequences, and maneuver for position.

for decision; (2) inventing, developing, and analyzing possible courses of action; and (3) selecting a particular course of action.[5] Katz and Kahn, drawing from John Dewey's early formulation of the stages of a decision process, characterize them as: (1) immediate pressures on the decision maker, (2) analysis of the type of problem and its basic dimensions, (3) the search for alternative solutions, and (4) the consideration of the consequences of alternative solutions leading up to final choice and post-decisional conflict.[6]

A number of conceptualizations of a decision process have taken the viewpoint that the process is made up of stages linked together into a sequence. For example, Brim _et al_. identify the stages of (1) identification of the problem; (2) obtaining necessary information; (3) production of possible solutions; (4) evaluation of these alternatives; (5) selection of a particular strategy (alternative); and (6) actual performance of action or actions and subsequent learning and revision.[7] Applewhite in his extensive review of the literature on decision-making cites the work of Litchfield wherein the decision process activities of (1) definition of the problem; (2) analysis of existing situation; (3) calculation and delineation of alternatives; (4) deliberation; and (5) choice, are identified.[8]

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[5] Simon, _op_. _cit_., p. 2.

[6] Daniel Katz and Robert L. Kahn, _The Social Psychology of Organizations_ (New York: John Wiley & Sons, Inc., 1966), p. 274.

[7] Brim, _et al_., _op_. _cit_., p. 9.

[8] Philip B. Applewhite, _Organizational Behavior_ (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1965), p. 56.

These and other process viewpoints of decision-making differ in degree rather than in kind. The specific steps or phases depend on the point of view taken and as Brim _et_ _al_. indicate, the situation.[9] The process point of view seems well established and consistent with respect to various researchers. Brim _et_ _al_. have observed the following concerning decision phase formulation:[10]

1. A particular decision may not involve all of the identified phases. For example, certain problems or tasks may not require obtaining new information. (All relevant information may be contained in the knowledge state of the individual or group seeking a solution to a problem.)

2. The conceptualization of decision process stages is applicable to the analysis of a broad range of decisions. Formal analysis in terms of basic phases of the process points up the similar nature of all decision problems.

3. There seems to be a linkage between decision process conceptualization and general intellectual functions such as insight, judgment, and intelligence.

4. Problem solving and the decision process seem to be much the same and tend to be used interchangeably.

The "search for information stage" of a decision process is of particular relevance to the present study. The extensive body of research concerning product adoption has contributed valuable insights regarding decision-making as a process.[11] In particular, these studies provide a better understanding of the role of information in decision-making. For example, Rogers has hypothesized concerning the role of information

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[9]Brim, _et_ _al_., _op_. _cit_., p. 10.

[10]_Ibid_., pp. 10-11.

[11]See North Central Rural Soçiology Committee, _Bibliography of Research on: Social Factors in the Adoption of Farm Practices_, Second ed. (Ames, Iowa: Iowa State College, March, 1959).

sources (impersonal and personal) with respect to different stages of the adoption process.[12]

Simon characterizes the decision-making phase of "searching the environment for conditions calling for decision as human intelligence activity."[13] He suggests the complexity of viewing problem solving in terms of phases in the following:

> "Generally speaking, intelligence activity precedes design, and design activity precedes choice. The cycle of phases is, however, far more complex than this sequence suggests. Each phase in making a complex decision is itself a complex decision-making process. The design phase, for example, may call for new intelligence activities; problems at given level generate subproblems that, in turn, have their intelligence, design, and choice phases, and so on."[14]

Different types of studies have been focused on the search for information decision process stage. Katona and Mueller in their study of purchase decisions developed an index of deliberation concerning these decisions and utilized as one of the elements of deliberation, the extent of information-seeking activity.[15] Marschak has taken an "economic" viewpoint of information in an analysis of the cost of new information versus the improvement of the overall utility of the solution.[16] This approach yields a set of conditions under which the tradeoff concerning new information is provided.

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[12]Everett M. Rogers, The Diffusion of Innovations (New York: Free Press of Glencoe, 1962), p. 99.

[13]Simon, op. cit., p. 2.

[14]Ibid., p. 4.

[15]George Katona and Eva Mueller, "A Study of Purchase Decisions," Consumer Behavior, ed. Lincoln H. Clark (New York: New York University Press, 1954), pp. 30-87.

[16]Jacob Marschak, "Value, Amount and Structure of Information, and the Cost of Decision Making," Behavioral Science, I (1965).

Classification of Decisions

To attempt to provide an orderly and complete classification system for all possible decisions would involve an extensive undertaking. The intent of this review of research is to identify task dimensions or characteristics which may serve as useful foundations for the conceptualization provided in Chapter 3. No attempt will be made to identify exhaustively the possible characteristics or dimensions of variation of a task or decision problem.

Brim *et al*. refer to the classification of decisions according to two groupings: (1) formal properties (theoretical and *abstract* characteristics of decisions which are independent of content or the substantive nature of the problems) and (2) *substantive* characteristics (such as economic problems, administrative decisions, career choices, mate selection, etc.).[17]

Classifications which are based on formal or abstract properties are large in number. The Brim *et al*. study made no attempt to develop an abstract ordering of the many decision characteristics referred to by other researchers. They point out that "a theoretical classification which exhausts the characteristics of decision processes is a major undertaking--a study in itself."[18] The characteristics utilized in their study are degree of certainty of outcome, state of nature (competitive, cooperative, and neutral), type of cost involved, repetitive play versus nonrepetitive performance, revocable versus irrevocable consequences,

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[17]Brim, *et al*., *op*. *cit*., p. 14.

[18]*Ibid*., p. 14.

method of choice versus single stimuli, and single or multiple significant classes of outcome.[19]

Classifications (with respect to substantive properties) typically have been based on the social context or role in which the decision occurs. Brim et al. suggest that "this is because roles include customs or rules for how one should attempt to solve a problem."[20] Classifications of this type are reflected in decision-making guides which provide lists of "factors to consider" in, for example, making finance, advertising, or cost accounting decisions. Brim et al. indicate that very little is known concerning the particular norms which regulate the decision-making process in different occupational roles.[21]

Situational characteristics may be viewed in terms of their bringing about certain responses on the part of individuals. Such a stimulus-response linkage (assuming that interest is in making predictions from knowledge of situations) is based on two assumptions: (1) equivalent individual reaction to indicated situations; (2) situational variables are influential enough to overcome any possible individual differences in reaction to them.[22]

Various approaches have been used to distinguish between different types of problems. Cohen and Cyert identify three dimensions for classifying the various types of economic decision problems: (1) the time

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[19] Ibid., pp. 15-17.

[20] Ibid., p. 17.

[21] Ibid., p. 18.

[22] Ibid., p. 22.

dimension; (2) the degree of information dimension (certainty, risk, and uncertainty); and (3) the degree of rationality dimension.[23] Simon distinguishes between programmed decisions and nonprogrammed decisions suggesting that they are polar types spanning a continuum.[24] Katz and Kahn view decision-making according to the following decision dimensions: level of generality or abstraction; amount of internal and external organizational space affected; and the time span of influence of the decision.[25] They suggest that the stages in the process are influenced by (1) the nature of the problem, (2) the organizational context, (3) the basic personality characteristics of the decision maker, and (4) the cognitive limitation of individuals with respect to situational and personality factors.[26] A similar association may exist between certain of these factors and information-processing.

Simon identifies programmed decisions as those which are repetitive and routine to the degree that definite procedures are indicated for handling them when they occur.[27] In contrast, he views nonprogrammed decisions as those invoking a response where the decision "system has no specific procedures to deal with situations like the one at hand, but

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[23]Kalman J. Cohen and Richard W. Cyert, Theory of the Firm: Resource Allocation in a Market Economy (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1965), p. 308.

[24]Simon, op. cit., p. 5.

[25]Katz and Kahn, op. cit., p. 259.

[26]Ibid., p. 274.

[27]Simon, op. cit., pp. 5-6.

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must fall back on whatever general capacity it has for intelligent, adaptive, problem-oriented action."[28]

Trull has formulated and tested a model made up of factors involved in determining total decision success.[29] His model suggests that decision success can be considered a function of decision quality plus implementation. One of the factors in the model is the "optimum amount of information" which suggests a way to link information with decision results.

Morris (as a part of a larger research program on negotiation and decision-making) has studied the effects of task characteristics on group process.[30] The specific objectives of the effort were to (1) help clarify the role of task characteristics in group performance; (2) provide detailed information concerning patterns of interaction behavior in task groups; and (3) establish a matrix of "baseline" data which could be utilized as a normative reference base for studying the effects of task, group structural, and compositional variables. The Morris study was concerned with the task characteristics of task type (production, discussion, problem solving) and the level of task difficulty. Supplementary data was also included on the influence of ordinal position of the task. The study involved 100 tasks; observations were accomplished on 108 three-man groups with each group handling four tasks.

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[28] Ibid., p. 6.

[29] Samuel G. Trull, "Some Factors Involved in Determining Total Decision Success," Management Science, XII (February, 1966), pp. B-270-B-280.

[30] Charles G. Morris, Effects of Task Characteristics on Group Process, Technical Report No. 2, AFOSR-65-1519 (Urbana, Ill.: University of Illinois, Department of Psychology, July, 1965).

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INDIVIDUAL THINKING PROCESS

The human thinking processes which are of particular interest in this study concern those conceptual viewpoints and variables which are related to problem solving behavior and in turn, information-processing behavior. The intent is to identify and examine research which provides useful conceptual insights and identification of individual variables of potential use in this research effort.

Kogan and Wallach have investigated human thinking and problem solving from the standpoint of the risks, potential costs, and potential gains that may face the individual as he proceeds in his efforts.[31] They considered cognitive-judgmental processes and intellective processes as possible correlates of decision-making using personality processes in the role of moderator variables.[32] Subjects (114 male and 103 female undergraduates) were located in one of four subgroups on the basis of the moderator variables of test anxiety and defensiveness. Using these subgroups relations among the major variables of the study were explored.[33]

The Kogan and Wallach variable system provides a useful frame of reference within which related research on human thinking processes can be viewed. Their review of the literature in these areas is excellent. Figure 2 illustrates and relates the variable groupings.

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[31]Nathan Kogan and Michael A. Wallach, _Risk Taking: A Study in Cognition and Personality_ (New York: Holt, Rinehart and Winston, 1964), p. 1.

[32]The idea behind a moderating variable is that of dividing a particular sample into subsets according to the existence and absence of a particular characteristic called a moderating variable. For example, the division of a sample of adults into males and females reflects the application of separating a possible moderating influence.

[33]Kogan and Wallach, _op. cit._, p. 17.

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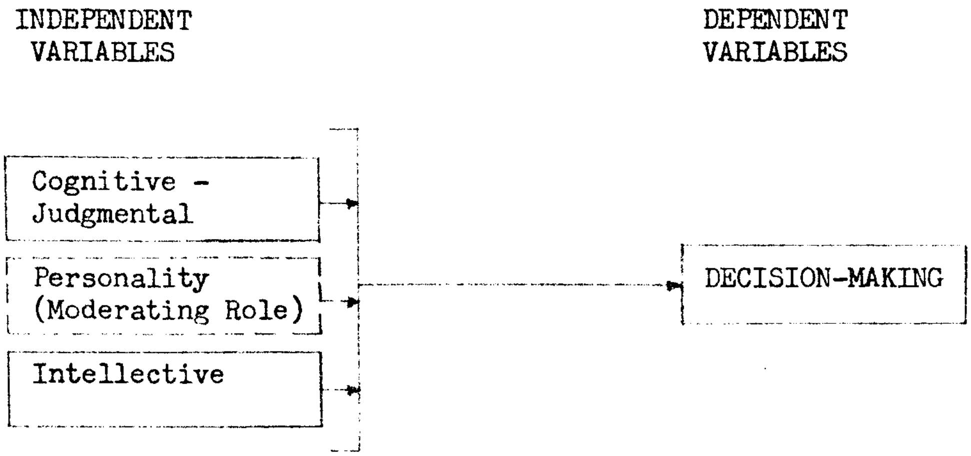

Figure 2 — Kogan and Wallach Variable System

It is important to note that there appears to be no generally agreed upon grouping of areas in the literature with respect to cognitive-judgmental, intellective, and personality processes. For example, some researchers group all three under personality characteristics. However, the Kogan and Wallach frame of reference seems reasonable. A category referring to individual and situation interaction is also included.

Intellective Processes

With regard to intellectual ability the following dimensions appear related to problem-solving: verbal comprehension, conceptual foresight, originality, and sensitivity to problems.[34] Individuals possessing these abilities would be expected to perform better on problem solving than those not having the abilities.

Kogan and Wallach point out that "information regarding the intellective correlates of decision making has been quite sparse."[35]

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[34]Applewhite, op. cit., p. 71.

[35]Kogan and Wallach, op. cit., p. 10.

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They investigated the relationship between risk-taking and three types of intellective skills: verbal aptitude, mathematical aptitude, and analytic functioning. Their results indicated the existence relationships between these variables and decision-making behavior; however, they suggest that the direction of causation may move from risk-taking disposition toward certain of the intellective skills.[36] Kogan and Wallach indicate that "the empirical evidence introduced, although indirect, is highly supportive of such an interpretation."[37]

Brim *et al*. suggest that a relationship between intelligence and problem solving as indicated by previous research is moderate to negligible:

> "These data suggest that decision-making characteristics probably depend much more on individual differences in training, and on the effects of temperament on personality which regulate the use of various intellective factors, rather than on such factors themselves."[38]

While the central focus of their study was on the relation of nonintellective factors to the decision process they did include a measure of verbal intelligence.

Cognitive Processes

Bruner, Goodnow, and Austin define cognitive processes as the means by which organisms achieve, retain and transform information.[39] These

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[36] *Ibid*., p. 120.

[37] *Ibid*., p. 121.

[38] Brim, *et al*., *op*. *cit*., p. 49.

[39] Jerome S. Bruner, Jacqueline J. Goodnow, and George A. Austin, *A Study of Thinking* (New York: John Wiley & Sons, Inc., 1956), p. vii.

researchers provided the impetus toward the conceptualization of various cognitive processes in strategy or problem solving terms.[40]

Bruner, Goodnow, and Austin in discussing concept attainment view the process as a series of decisions.[41] Their objective in studying concept attainment was to:

> "externalize for observation as many of the decisions as could possibly be brought into the open in the hope that regularities in these decisions might provide the basis for making inferences about the processes involved in learning or attaining a concept. These regularities in decision-making we shall call strategies."[42]

They view a strategy as a "pattern of decisions in the utilization of information that serves to meet certain objectives."[43] This viewpoint appears similar to that of looking at decision-making as an information-processing effort.

Bruner, Goodnow, and Austin have grouped the conditions influencing concept-attainment behavior as follows:[44]

1. Definition of the task.
2. Nature of the instances encountered.
3. Nature of the validation.
4. Consequences of specific categorizations.
5. Nature of imposed restrictions.

Research on technical decision-making under uncertainty has revealed that individuals tend to choose less risky alternatives in the face of

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[40]Kogan and Wallach, _op_. _cit_., p. 2.

[41]Bruner, Goodnow, and Austin, _op_. _cit_., p. 54.

[42]_Ibid_., p. 54.

[43]_Ibid_., p. 54.

[44]_Ibid_., p. 56.

uncertainty than in comparable risk problems with greater certainty.[45] Of related interest is the work done by Soelberg on the design of a complex, computer controlled problematical environment which is sufficiently: (1) complex and flexible to provide long-term systematic investigations of human thinking processes; (2) well specified to permit application of rigorous experimental controls; and (3) quantifiable to allow explicit measurement of behavior as well as direct comparison of alternative strategies of problem solving.[46]

Eyring has investigated sources of uncertainty in engineering design projects.[47] The focus of the study was to identify what first-level technical supervisors perceive as the causes of uncertainty in their design work. Two primary sources of uncertainty were identified: (1) unknown problem difficulty and (2) possible changes in specifications defining the problems. These are subdivided into several subsidiary sources.[48]

The work of Kogan and Wallach represents an attempt to examine exhaustively the risk-taking implications of certain cognitive-judgmental processes. They utilized three measures in their study. The importance of the Kogan and Wallach research lies in the identification of possible relationships between cognitive processes and risk-taking. Their results are indicated by the following:

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[45] Donald G. Marquis, Annual Report: Research Program on the Management of Science and Technology, 1964-1965 (Cambridge, Mass.: Massachusetts Institute of Technology, July, 1965), pp. 6-7.

[46] Ibid., p. 7.

[47] H. B. Eyring, Some Sources of Uncertainty in Engineering Design Projects, RM-4503-PR (Santa Monica, Calif.: The Rand Corporation, October, 1965).

[48] Ibid., p. v.

> "In sum, we have been able to demonstrate that various cognitive-judgmental behaviors—namely, general confidence of judgment, breadth of categorizing, extremity concerning judgments about external events, and extremity concerning self-referent judgments—do possess particular kinds of risk-conservatism implications for particular subgroups of individuals."[49]

An individual's data (information) processing limits as related to decision-making is a cognitive process of relevance to the present study. Hayes utilized 16 naval enlisted men in four experiments involving a simulated military problem.[50] The task utilized was that of assigning one of several alternative aircraft to investigate the sighting of reported enemy submarine.

The similated task was a data matrix providing several airplane alternatives, each with a certain characteristic that varied in terms of desirability such as pilot, armament, take-off delay, search time, and distance. Hayes constructed 240 different data matrices on a random basis.

Subjects were required to choose among alternatives on the basis of two, four, six, or eight relevant facts. Decision quality and decision time were measured. Hayes found that more than four facts caused a decrease in decision-making efficiency. His research suggests a possible approach to measuring an individual's information-processing efficiency.

An area related to an individual's information processing limits is the concept of "information overload." Brown has discussed information overload and the adjustment processes of an organization that may

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[49]Kogan and Wallach, op. cit., p. 199.

[50]John R. Hayes, Human Data Processing Limits in Decision Making, Report No. ESD-TDR-62-48 (Bedford, Mass.: Air Force Systems Command, Electronic Systems Division, July, 1962).

result when its information system is loaded in excess of capacity.[51] Brown cites J. G. Miller's categorization of organizational responses to information overload which include omission, error, queuing, filtering, approximation, multiple channels (parallel transmission), and escape.[52]

Personality Processes

Brim *et al*. have identified those characteristics of an individual with respect to *abilities*, *beliefs*, *attitudes*, and *motives* as the individual's personality.[53] A somewhat more narrow viewpoint has been taken in this analysis by considering abilities separately as intellective processes. Research foundations of primary interest with respect to personality processes are those linking personality with decision processes. The Brim *et al*. categories of motives and beliefs will be used as a frame of reference for examining personality processes.

There are certain underlying assumptions when predictions are anticipated from personality characteristics. Drawing from Brim *et al*. these assumptions are:[54]

1. The characteristics are stable over time; they do not change.
2. A personality variable has generality--it is applicable in many situations.

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[51]Warren B. Brown, "Systems, Boundaries, and Information Flow," *Journal of the Academy of Management*, IX (December, 1966), pp. 323-324.

[52]*Ibid*., p. 324.

[53]Brim, *et al*., *op*. *cit*., p. 46.

[54]*Ibid*., pp. 46-47.

Brim et al. in considering motivation designate:

> "a concept of bodily tensions or energies which underlie and generate behavior. These drives in the individual impel him to act, and thus modify them to his satisfaction."[55]

They studied four specific aspects of motivation: (1) level of drive; (2) desire for certainty; (3) effect of unconscious motivational factors; and (4) personality traits.

In the area of beliefs Brim et al. suggest that the evidence is limited as regarding the relationship of beliefs to the decision process.[56] They divided the area into beliefs concerned with the characteristics of nature and those involving the relations of means to ends.

Brim et al. also utilized in their study certain characteristics of social groups as explanatory variables. They used males and females and groupings by social class. They observed the following with respect to these structural variations:

> "The theory leading to the use of these structural variations is that they have a probable relation to personality types, which in turn may be related to decision-making. Nevertheless, it is important to realize that this assumed sequence of causality running from social structure to personality, and then to decision characteristics, may in some instances not appear because of inadequacies of measurement or because of a lack of articulation between the three panels of variables, in spite of our initial theory which led to their selection."[57]

The use of personality characteristics as explanatory variables necessitates an appropriate range of variation among subjects. Brim et al.

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[55] Ibid., p. 50.

[56] Ibid., p. 54.

[57] Ibid., p. 59.

used two social classes and males and females in a deliberate effort to expand the range of variation in the personalities of their subjects.[58]

Kogan and Wallach found that a particular personality variable may have a very different meaning with regard to other psychological characteristics.[59] While far from being conclusive the results from their investigations of relationships between personality and risk-taking were complementary to the total research project. In commenting on this they indicate that:

> "The data are quite revealing of some of the personality dimensions that have an impact upon risk taking. As a valuable by-product we have acquired a deeper knowledge of the kinds of psychological processes tapped by some of the better-known scales."[60]

It is possible that the risk-taking dimension may serve as a proxy for an individual's personality dimension. In this capacity risk-taking could be viewed as a possible correlate of individual information-processing. Kogan and Wallach suggest that "there are indications in the present work that the risk-conservatism dimension may have implications for a wide variety of behavioral and social phenomena."[61]

Individual and Situation Interaction

This area concerns the interaction of individual variables and those pertaining to the situation such as a task. In the Brim *et al.* study their analysis was approached as follows:

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[58] *Ibid.*, p. 59.

[59] Kogan and Wallach, *op. cit.*, p. 202.

[60] *Ibid.*, p. 202.

[61] *Ibid.*, p. 205.

"What we have done in our analysis is to deal first with the direct effects of personality, regardless of the situation; second, to deal with the effects of situations, irrespective of personality; and third, to hypothesize that certain momentary states must have resulted from the interaction of these two sets of variables, and thus to look at the effects of interaction on the decisions."[62]

Brim *et al*. identified three situational variables: (1) type of problem; (2) group versus individual problem solving; and (3) order of and familiarity with the problem.[63] By problem type they refer to variation with respect to substantive properties as discussed earlier in the chapter.

Information theory as extended and generalized by Claude E. Shannon and Norbert Wiener offers possible insights into individual and situation interaction.[64] There have been many contributions and extensions to the basic theory that was developed in the late 1940's. Information theory grew out of the general philosophy of communication theory. Shannon's work was centered in the area of engineering communication while Weiner was interested in biological applications.[65]

Information in the context of the theory is defined as a measure of one's freedom of choice in selecting a message and is not to be confused with information in terms of "meaning":

"In fact, two messages, one of which is heavily loaded with meaning and the other of which is pure nonsense, can be exactly equivalent, from the present viewpoint, as regards information."[66]

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[62] Brim *et al*., *op*. *cit*., p. 46.

[63] *Ibid*., pp. 60-62.

[64] Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana, Ill.: The University of Illinois Press, 1964).

[65] *Ibid*., p. 3.

[66] *Ibid*., pp. 8-9.

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The greater the uncertainty about the outcome of a message state, the greater the amount of information associated with the outcome. No information is conveyed if an outcome of a given message state can be predicted in advance. Information theory bases the measure of information of a message state on the probability of that message state occurring.[67]

The mathematical expression for the measure of information according to the meaning of the theory is that utilized for "entropy" drawn from thermodynamics. Specifically, the amount of information is measured in terms of the logorithm of the number of available choices:[68]

$$H = \text{measure of information} = -\sum_i P_i \log P_i$$

(The minus sign is necessary to make "H" a positive value.)

In terms of this expression the higher the probability associated with a given source the lower the value of H. For example, if a particular source has the probability of one then the value of $H = 0$. The key element in the theory is the special meaning of information:

> "Information is, we must steadily remember, a measure of ones freedom of choice in selecting a message. The greater this freedom of choice, and hence the greater the information, the greater is the uncertainty that the message actually selected is some particular one. Thus, greater freedom of choice, greater uncertainty, greater information go hand in hand."[69]

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[67] John C. Hancock, An Introduction to the Principles of Communication Theory (New York: McGraw-Hill Book Company, Inc., 1961), p. 156.

[68] Shannon and Weaver, op. cit., p. 9.

[69] Ibid., p. 18.

Two Russian psychologists have utilized information theory concepts in the study of human abilities.[70] Their research was directed toward demonstrating, via a limited data base, the feasibility, desirability, and techniques associated with using information theory in the study of human abilities.

Shapiro and Umanskiy have applied the theory in an unusual way to develop an "information characteristic" which is defined as an index of the difficulty of a multidimensional problem.[71] They have used this index to achieve a quantitative scaling of task difficulty.

The Russian research utilized the planning and execution of an organizational task as a vehicle for studying choice behavior in a probability maze. Measurement was accomplished by using the entropy measurement concept of information theory. The study was conducted on a multi-stage basis utilizing as a task project responsibility for directing a group of students in the manufacture of toys for youngsters in a kolkhoz-sponsored kindergarten.[72]

Conceiving of human beings as communication systems in the context of information theory suggests a useful research foundation for this study. In particular the Russian research suggests that an individual's state of knowledge concerning a task may be measured on a quantitative scale utilizing the entropy concept of information theory.

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[70] S. I. Shapiro and L. I. Umanskiy, "Using Information Theory for Studying Human Abilities," Voprosy Psikhologii (Problems of Psychology), (August 16, 1963), pp. 75-90. Translated into English by Joint Publications Research Service, Washington, D.C. JPRS-20680.

[71] Ibid., p. 12.

[72] Ibid., p. 15.

INFORMATION-PROCESSING

Information-processing in the context of this study refers to the search, evaluation, and use of information in problem solving. The areas of research that provide foundations for the present effort concern work where information-processing is associated with problem solving or decision-making. Rigby suggests that "a key element in problem solving is securing information on the system and on the environment."[73] The role of information in the decision process was discussed earlier in the chapter where a stage of the process was identified as the search for information.

It is important to note that the research areas of primary concern to the present study are those relating to individual information-processing rather than the extensive body of work dealing with formal information systems such as computerized information systems.[74] The focus is on the individual as a processor of information during his problem solving efforts. Further, interest in information goes beyond the search for information. The concern is with information during the entire decision-making process.

Research on individual information-processing can be examined in terms of total process studies, specific fragments of the process, and highly specialized efforts. These foundations are identified and examined

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[73]Paul H. Rigby, Conceptual Foundations of Business Research (New York: John Wiley and Sons, Inc., 1965), p. 6.

[74]See John Diebold, "What's Ahead in Information Technology," Harvard Business Review, XLIII (September-October, 1965), pp. 76-82, for a discussion of the state of the art of information-processing with respect to sensing, transmitting, storing, reducing, and reporting information.

in terms of possible conceptual guidelines, variable identification and methological insights. The bulk of research on information-processing has been centered either on the examination of user's information needs or alternatively on selected phases of an individual's information-processing activity.

Process Studies

The concept of technical problem solving as an information-processing task has been suggested by several researchers. The Auerbach study views scientific and technical functions as the transformation of information inputs into outputs.[75] Weinberg considers the information process an integral part of the research process.[76] Roberts has used an "Industrial Dynamics" type model with flows of information associated with the life cycle of a weapon system development project.[77] Brandenburg and Stedry have formulated a multi-stage information conversion model of the R & D process.[78] The analogy between technical problem solving and information-processing seems reasonable. Results are in the form of knowledge or information rather than physical outputs.

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[75] Auerbach Corporation, DOD User Needs Study, Phase I-Vol. I (AD-615501), May 14, 1965 (Philadelphia: Auerbach Corporation, 1965).

[76] The President's Science Advisory Committee, Science, Government, and Information (Washington, D.C.: U. S. Government Printing Office, January 10, 1963), p. 14.

[77] Richard G. Brandenburg and Andrew C. Stedry, Toward A Multi-Stage Information Conversion Model of the Research and Development Process (Pittsburgh, Pa.: Graduate School of Industrial Administration, Carnegie Institute of Technology, August, 1965), p. 3.

[78] Ibid.

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Paisley entitles his excellent literature review "The Flow of (Behavioral) Science Information: A Review of the Literature."[79] He notes, however, that with only a few exceptions such literature does not exist. Accordingly, he directs his efforts toward a very comprehensive and careful review of the body of research focusing on the information-gathering and disseminating behavior of physicists, chemists, zoologists, and engineers. He observes that the information-processing behavior of these various scientific and technical people does not seem to be affected greatly by the particular field of research.[80] The Paisley review provides a useful evaluation of past research on the information-processing characteristics of scientific and technical people. He covers the literature from the apparent emergence of such studies through 1965. The review offers a valuable guide and cross check to work related to this study.

Rather than to follow in Paisley's footsteps by critically examining the numerous studies assessed so well by him, an attempt will be made to identify several important and relevant generalizations which seem to emerge from his review.

1. Most of the studies have investigated information use at a point in time rather than over a time span.

2. The bulk of the work has been highly specialized. Due to conceptual and methodological variation it is difficult to compare various projects in any useful way.

3. Previous studies have not taken a task oriented focus with respect to information use.

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[79]W. J. Paisley, The Flow of (Behavioral) Science Information: A Review of the Research Literature (Stanford, Calif.: Stanford University Press, Institute for Communication Research, 1966).

[80]Ibid., p. I-1.

4. The studies have been concentrated on specific fragments of information-processing with a high proportion falling into the area of information search.

The Auerbach Corporation conducted an extensive study in 1964 for the Department of Defense (DOD) to collect and analyze a statistically significant data base on how scientists and engineers presently acquire and utilize technical information in the performance of their tasks.[81] The emphasis of the study was on the searching phase of individual information-processing. Data was obtained from two hour (one time) interviews with government scientists and engineers. The methodology was formulated and executed on a sound basis. The analysis is excellent. Paisley observes that this study has not received the recognition it is entitled to as a major contribution to information-flow research. He suggests that "the soundness of its methodology and analysis marks this study as unique."[82]

The major thrust of the Auerbach study concerned information sought for and used by DOD research, development, test, and evaluation personnel to perform specific tasks. The conceptual viewpoint was that of information-processing with respect to task oriented behavior as contrasted to information-processing for the purpose of general knowledge or current awareness.

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[81]Auerbach, op. cit.

[82]Paisley, op. cit., p. II-47.

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The Auerbach study defined the information "chunk" as the basic unit of analysis.[83] Indicated below are the major independent and dependent variables included in the study:[84]

Independent Variables	Dependent Variables (by chunk)
educational background	function
field of research	source
kind of task	time to obtain
task output	depth of information provided
	value to task

The Auerbach study utilized a simple random sample of 1375 drawn from a population of 36,000 scientists and engineers. As an example of the study findings "in more than half of the task related searches RDT&E personnel utilized colleagues, personal files, and local departmental sources as their first source of information."[85] With respect to volume of information used they found that only about 16% of the time did the subjects see (based on the individual's assessment) all the available information for a task.[86]

Perhaps the most significant limitation of the Auerbach research is that while a process viewpoint was taken, data collection was on a one-time basis. Additionally, there was a significant variation with respect to the tasks included in the study. The effort does provide important

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[83]Auerbach, op. cit., p. A-5. They define the "chunk" as the smallest identifiable unit of task-required information which would lose its identity with respect to the task if broken down further.

[84]Ibid.

[85]Ibid., p. I-12.

[86]Ibid., p. I-10.

insights concerning individual information-processing, variables, and methodology. The information chunk or element of information suggests a meaningful unit of analysis for the present study.

Meister and Farr have developed tests to measure the utilization of human factors information by designers and have administered the tests to ten packaging designers.[87] The research attempted to investigate the designer's analytic process for the purpose of gaining findings which would help to remove communication blocks and thus contribute to design improvement. The research centered on the decision-process of solving design problems including the gathering and analysis of informational inputs from diverse sources and the application of these inputs to the related design tasks.

A study has been proposed by the Bunker-Ramo Corporation which is similar in several aspects to the present research effort.[88] The proposed project involves a 15-month study of information usage among the scientists and engineers located at the firm's Canoga Park, California facility. The study will seek to overcome a number of the limitations present in previous information use investigations. Specifically, the research will include the following key elements:[89]

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[87] David Meister and Donald E. Farr, The Utilization of Human Factors Information by Designers, Paper presented to the Human Factors Society, Anaheim, Calif. (Canoga Park, Calif.: Bunker-Ramo Corporation, November, 1966).

[88] The Bunker-Ramo Corporation, Proposal for the Study of Information Utilization in the Industrial Environment, No. 5612-012-6U1 (Canoga Park, Calif.: The Bunker-Ramo Corporation, Defense Systems Division, August, 1966).

[89] Ibid., p. 1.

1. A technique called "interactive observation" will be used. This involves the investigator as an integral part of the research environment. He will seek to become intimately familiar with personal working on the projects studied and will actually participate.

2. Information usage will be studied in the context of actual problem solving behavior--specifically research and development activity. Thus, information usage is viewed as a part of the problem solving process.

3. The study will be concerned with information use beyond the search for information. The focus will be on information use behavior ranging from search through to the integration of the information into the task.

4. Investigation of the interaction of organizational with individual channels of information will be an important part of the study.

The proposed Bunker-Ramo study will develop complete and detailed data on each subject's information use activities. The results of the research are intended to provide a set of guidelines for designing organizational information systems with respect to the needs of the individual user.[90]

Ammerman in developing a model of officer job behavior has taken an information-processing view of purposive behavior of individuals.[91] The major components of the model include job goals and standards, selection of a plan of action, action to obtain information, integration of information, making of determinations, and action to control the situation.[92] The Ammerman conceptual model suggests a close linkage between information-processing and decision-making.

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[90] Ibid., p. 2.

[91] Harry L. Ammerman, A Model of Junior Officer Jobs for Use in Developing Task Inventories, Technical Report 65-10 (Alexandra, Va.: George Washington University, Human Resources Research Office, November, 1965).

[92] Ibid., pp. 20-24.

Kaplan and Newman have developed a theory of information-processing based on elements of Bayesian statistical decision theory.[93] The theory is called Probabilistic Information Processing (PIP). It builds on the work of Ward Edwards and others where the theory was developed to aid in making diagnostic decisions.[94] Diagnosis in the context used in the PIP theory concerns deciding which one of several possible states of the world is most plausible. This type of diagnosis involves information search, processing, and integration into an individual's decision-making process. The Bayesian framework provides for an orderly integration of information into the decision process.

Kaplan and Newman performed three experiments in the area of military command and control information-processing. The experimentation involved three independent variables identified as condition, content, and difficulty.[95] The dependent variable was the subject's subjective estimate of probabilities for both PIP and Non-PIP conditions. Their results generally supported the superiority of the PIP decision framework for processing data to make the data more effective for inference and decision.

Process Fragments

Process fragments refer to specific phases or aspects of information-processing. The most extensive body of research relating to individual

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[93]Richard J. Kaplan and J. Robert Newman, Studies in Probabilistic Information Processing, SP-1743/000/00 (Santa Monica, Calif.: System Development Corporation, October 2, 1964).

[94]Ibid., p. 5.

[95]Ibid., p. 12.

information-processing deals with information use patterns. One result of the Auerbach study was a bibliography of information user need studies.[96] Nearly 700 listings were included in the literature survey. The number of previous user need studies does not appear to have answered the many questions surrounding individual information searching. The Auerbach study suggests that user needs are neither broadly known nor well understood.[97]

Paisley observes that "studies of scientists' information-processing activities have become known generically as use studies."[98] He suggests that most of these use studies are mutually duplicative but that no indicated effort has been made to replicate methods. Accordingly, there is an extensive "collection" of case studies whose findings can be compared only if a ceteris paribus assumption is stretched over gross differences in procedure.[99]

MacLaughlin, Rosenbloom, and Wolek have studied the acquisition of useful technical information by scientists and engineers in five divisions of a large industrial corporation.[100] Their method of analysis involved the cross-tabulation of dependent variables (characterizing the means of

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[96] Auerbach, op. cit., p. C-1.

[97] Ibid., p. I-2.

[98] Paisley, op. cit., p. II-1.

[99] Ibid., p. II-1.

[100] Curtis P. MacLaughlin, Richard S. Rosenbloom, and Francis W. Wolek, Technology Transfer and the Flow of Technical Information in a Large Industrial Corporation, PB-173457 (Cambridge, Mass.: Harvard University, Graduate School of Business Administration, March, 1965).

acquisition) against a series of situational and personal independent variables. For example, independent variables such as corporate organization, field of science, education, and experience were examined with respect to the dependent variable, information source.

They collected data on more than 1200 instances of information acquisition via self-administered questionnaires from 430 respondents. Supplementary data was obtained by personal interviews with 30 respondents. Their results suggest that the transfer of technical information involves a complex social process in which technology, personal characteristics, organizational values and structure, and the beliefs of professional subcultures interact to influence information acquisition behavior.

Research tending to support the concept of "local search" for information is indicated in a study of the information sources for choice and definition of problems accomplished by Stoney on the basis of questionnaire responses from 157 research professionals (NASA personnel). Findings indicated that the most frequent source of ideas was the researcher's supervisor. Work experience and literature were second in frequency for the total sample.[101]

Rubenstein and Rath have analyzed the actual needs of R & D people for technical information including the timing, form of information required, and the adequacy of existing information systems to meet these needs. A series of simulations ranging from very simple, completely human-linked systems to complex, man-machine systems are contemplated.[102]

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[101]Marquis, op. cit., pp. 17-18.

[102]National Science Foundation, Current Projects on Economic and Social Implications of Science and Technology, NSF 65-16 (Washington, D.C.: U. S. Government Printing Office, June, 1965), p. 97.

Allen and Andrien examined four government funded parallel research and development projects to determine the manner in which engineers and scientists allocate their time and the effect of this allocation on the outcome of the projects.[103] They found that the percentage of total time spent in three categories of information gathering (outside consultation, staff consultation, and literature search) varies significantly over the life of a project. Subsystems reflecting greater uncertainty receive a higher percent of information gathering time than subsystems when uncertainty is lower. Allen and Andrien found that higher rated research teams are relatively stable in all phases of information gathering while lower rated teams initially spend far more time gathering information than they do in the later stages and fluctuate more throughout the project. These findings suggest that: (1) uncertainty relative to a task outcome and search investment (time) are positively associated and (2) group job performance and search investment are associated.

Golovan, Luk, and Starinets in their research on simulating certain properties of the memory emphasize the multi-dimensional, interrelated, complex nature of individual information-processing.[104] They discuss the processes by which man reproduces information with particular focus on the role of associations, the value of logical transformations which are realized in associative memory, the role of information coding, the

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[103] Thomas J. Allen and Maurice P. Andrien Jr., <u>Time Allocation Among Three Technical Information Channels by R and D Engineers</u> (Cambridge, Mass.: Massachusetts Institute of Technology, Alfred P. Sloan School of Management, August, 1965).

[104] E. T. Golovan, A. N. Luk and V. S. Starinets, "Simulating Certain Properties of the Memory," <u>Priroda</u> (Moscow), (December 13, 1965) pp. 45-60. Translated into English by Joint Publications Research Service, Washington, D.C., JPRS-33298.

importance of time in organization of memory, and the role of feedback in the process of information reproduction.

In a study involving 94 industrial and governmental professional research and non-research personnel Rosenberg found a high correlation between preference ranking and the ease of use of eight information gathering methods.[105] A structural questionnaire was utilized with subjects indicating a preference to information gathering methods with respect to given hypothetical situations. Variables utilized included ease of use and amount of information expected. No significant correlation was found between preference ranking and amount of information ratings. The primary findings of the study suggest ease of use as an important variable regarding information gathering methods.

Glanzer has a continuing research effort underway on the coding and use of information in problem solving by individuals.[106] The research is centered on the encoding and storage mechanisms used by human subjects. The research concerns the following areas: (1) analysis of the relation between verbalization length and figure difficulty for a variety of sets of dot-patterns; (2) evaluation of the effect of encoding training on perceptual performance; and (3) examination of the effects of post-stimulus delay.[107]

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[105] Victor Rosenberg, The Application of Psychometric Techniques to Determine the Attitudes of Individuals Toward Information Seeking and the Effect of the Individual's Organizational Status on These Attitudes (Bethlehem, Pa.: Lehigh University, Center for the Information Sciences, July, 1966).

[106] Murray Glanzer, Coding and Use of Information in Problem Solving, No. DA-49-193-MD-2496 (New York: New York University, May 31, 1965).

[107] Ibid., p. 4.

Specialized Studies

A number of research efforts have been conducted with respect to highly specialized information-processing tasks. Several of these studies have been under the direction of the Decision Science Laboratory, Electronic Systems Division, Air Force Systems Command. While the work has primarily concerned information-processing relative to such tasks as weather messages, there are elements of the research which appear relevant to this study.

Kershner and Avery conducted a human factors evaluation of an electroluminescent display designed for the presentation of around-the-base weather messages.[108] They concluded that high-error personnel can be identified via the development of time and error normative data for a standard set of weather messages. Their research utilized decision time and error as independent variables influencing individual information-processing. They suggest "that the term 'error prone' may become as useful as a term in information-processing as has "accident prone" in traffic and industry research.[109]

Another similar study investigated the effects of console design and information sequence on short-term memory during information-processing.[110] The underlying focus of the research is that of learning

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[108]Alan M. Kershner and Donald L. Avery, A Study in Information Processing: Electroluminescent vs Teletype Readability of Weather Messages (Bedford, Mass.: Air Force Systems Command, Electronic Systems Division, December, 1965).

[109]Ibid., p. 9.

[110]Bernard P. Zeigler and Thomas B. Sheridan, Human Use of Short Term Memory in Processing Information on a Console, Technical Documentary Report No. ESD-TDR-64-620. (Bedford, Mass.: Air Force Systems Command, Electronic Systems Division, September, 1964).

more concerning human thought processes which will facilitate the design of form and content of information provided via computer-aided thinking. The following characterizes the central thrust of the study:

> "We have used the underlying principle that the manner in which information is stored in human memory determines the manner in which it may be retrieved and the basic assumption that the storage structures normally set up in human memory are fashioned by the order in which information is attended to. Both ideas have implications for general console design as it affects the human processor. For example, information handling procedures may be unwittingly forced upon the operator by the design of the console and the sequence in which information is presented. Internal storage structures so established may be efficient in response to certain questions but ill-suited in answer to others."[111]

CRITICAL RESUME' OF RELATED RESEARCH

The research dimensions of the decision-making process, individual thinking processes, and information-processing have been explored in detail. The work which has been identified is extensive. It does not fall neatly into an orderly and meaningful body of knowledge pertaining to individual information-processing and decision-making. However, there are several findings which are applicable to the present study. Likewise, there are certain limitations which need to be recognized.

Applicable Findings

Looking back over the research foundations that have been discussed in the chapter, it is appropriate at this point to summarize how these findings tie into the present study. Additionally, a number of specific

[111] *Ibid.*, p. 37.

observations have been made at various points in the chapter concerning the nature of the applicability of these findings to this research. The integration of specific findings is accomplished in the next chapter.

A logical analytical structure for this research emerges from certain of the previous efforts. A large body of research has been directed toward establishing a causal linkage between variables pertaining to the individual and the situation on one hand and decision-making on the other. The typical approach utilized in these studies has been to select a limited number of independent and dependent variables, develop an appropriate group of measuring instruments, and then investigate the existence of relationships via multivariate analysis. The Brim _et al._ study represents this approach.[112] The Kogan and Wallach research uses a multivariate frame of reference.[113] A similar approach to these studies seems appropriate for this exploratory research.

Certain studies have placed variables into groups or sets. In the Kogan and Wallach study the independent sets consist of cognitive-judgmental, personality, and intellective variables plus a set of dependent decision-making variables.[114] Such an approach provides an analytical framework within which various relationships of interest can be investigated.

In most of these research efforts the concept of viewing decision-making as a process (set of interrelated stages) has not been utilized

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[112]Brim _et al._, _op. cit._

[113]Kogan and Wallach, _op. cit._

[114]_Ibid._

as an analytical approach. An exception to this was the Brim study where a simplified decision process viewpoint provided the analytical focus.[115]

The logic of an information-processing viewpoint of decision-making seems clear, at least in general terms. The role of information-processing in the decision process is well substantiated. A possible linkage between explanatory individual and situational variables and information-processing variables appears to be a meaningful area of investigation.

The extensive base of findings on decision-making, phases of information-processing, and individual decision makers is applicable to the proposed study in a number of ways: (1) Fragments of work suggest meaningful variables (both dependent and independent) for inclusion in a conceptual model; (2) A number of related research findings offer insights concerning relationships for investigation; and (3) Several efforts provide useful guidelines for classifying data with regard to particular variables of interest.

The research foundations explored in some detail in this chapter are integrated, where applicable, in the conceptual variable system developed in the next chapter. Before moving ahead to this task it is important to identify in what ways the present study is unique as compared to previous related research.

Limitations

Although there are a number of research foundations applicable to the present study, no directly comparable work has been identified.

[115]Brim _et al._, _op._ _cit._

Perhaps, the most similar is the proposed effort by Bunker-Ramo discussed earlier in the chapter.[116] The limitations of previous research with respect to providing foundations for the present research need to be made explicit.

The use of a process viewpoint as an analytical frame of reference must recognize the iterative, interrelated and feedback nature of a sequential process. Care must be taken to utilize a basic unit of analysis that will be responsive to the problems of feedback and interrelationships.

The possibilities for a conceptualization of variables with respect to the individual, the situation, and information-processing are overwhelming. The range of choice is almost unlimited. Certainly, a manageable research effort cannot hope to result in an all inclusive variable system.

A number of variables have been identified which impinge in varying degrees of sensitivity upon the decision-making area. A similar linkage has been established between information-processing and decision-making. However, a definite relationship between decision-making correlates and information-processing is by no means clearly indicated, although such a linkage is suggested.

Much of the work in the information-processing area has been concentrated on certain stages or fragments of the decision process rather than on the total process. A large number of studies have been concerned with the user's search for information rather than information-processing

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[116] Bunker-Ramo, op. cit.

relative to a task oriented decision process. There has been no attempt to link together in any comprehensive manner information-processing variables which can be described by characteristics of the individual and the task.[117]

A number of studies have concentrated on an individual's uses of information with no attempt to consider information use in the context of a decision process. These studies have been for the most part limited in scope and of questionable value in describing individual information-processing behavior.

Little study has been directed toward the transformation phase of information-processing in terms of how the problem solver evaluates information inputs, what he does with them, and factors influencing the significance of information inputs during the various stages of processing information.

The identification of information seeking as a phase of the decision-process is well established. Yet, to study only this phase in the context of the present research effort would be too limited in scope recognizing the linkage and recycling among stages of the problem solver. An important orientation of this study is to consider information-processing during the entire decision-process rather than to arbitrarily identify an information collection phase of the total process.

[117]The only exceptions to this are the specialized studies discussed earlier in the chapter in the area of human factors analysis. These studies are used as inputs to the development of complex man-machine systems.

CHAPTER 3

CONCEPTUAL ANALYTICAL STRUCTURE

The task in this chapter is the formulation of a conceptual analytical framework to aid in describing individual information-processing during the problem solving process. An analytical model or variable structure is necessary to link together applicable concepts and to provide a basis for targeting relationships to be investigated empirically.

In view of the exploratory nature of this study there is no unified body of theory from which to draw. The effort is intended to suggest new insights into individual information-processing and perhaps to develop new concepts. Rigorous tests of carefully formulated hypotheses are not intended.

The framework should be viewed as a classification system for linking together variables and relationships. The objective in developing this conceptual structure is to provide a flexible insight into individual information-processing and at the same time insure that orderly inquiry takes place. Conceptual building blocks will be organized with respect to an information-processing viewpoint of decision-making.

The variables which are included in this conceptual formulation appear to be the most important elements with respect to the individual, the task, and information-processing. Those selected seem to be likely choices in terms of the research objective, prior research, time and financial constraints inherent in an exploratory study of this type, and the logic reflected by the variables which have been chosen.

The plan of the chapter is first to establish certain analytical dimensions of the study. Next, the variable system is developed. Finally, a set of relationships to be investigated is identified and discussed.

ANALYTICAL DIMENSIONS

In this section certain analytical dimensions of the study are discussed. First, several basic assumptions underlying the effort require explanation. Next, a number of basic definitions is needed in establishing reference points. Finally, the domains of variables pertinent to the research require clarification.

Assumptions

The following assumptions characterize the conceptual focus of the study:

1. The environment of interest is that encompassing individual technical people making decisions at the technical level.[1]

2. Individual information-processing is considered a subset of the decision-making domain. It is assumed that those causal influences impinging upon the decision-making domain may also

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[1]Warren B. Brown in "Systems, Boundaries, and Information Flow," Journal of the Academy of Management, IV (December, 1966), pp. 318-327, drawing from T. Parsons and R. M. Anthony, identifies three traditional levels of decision-making in organizations: (1) the institutional level for strategic planning; (2) the managerial level concerned with gathering, coordinating, and allocating resources for the organization, and (3) the technical level involving the acquisition and utilization of technical knowledge in the accomplishment of operational actions. In this context the present study is concerned with decisions relative to technical knowledge in the carrying out of operational actions.

influence information-processing. This does not infer that the existence of one influence necessarily implies the other. Rather, the implication is that correlates of decision-making may be suggestive of possible correlates of information-processing, thus identifying potentially fruitful directions of inquiry.

3. The objective of the study is to describe rather than to predict the information-processing behavior of individuals.

4. The study is not concerned with the identification of tasks or problems to be solved. Rather, the existence of tasks requiring solutions will be taken as given.

5. The direction of causality is assumed to move from those characteristics pertaining to the individual and/or the task toward information-processing behavior within a given environment.

6. It is assumed that information is used by an individual in seeking to solve a problem or to meet a particular need. In other words information use has a purposive orientation and is an integral part of decision-making.

7. The tasks of interest in the study are those which are the responsibility of individual technical people. It is assumed that tasks can be identified for which an individual provides the major output of the task. This particular task orientation does not assume that there will be no interaction with other individuals relative to a particular task.

Definitions

A number of definitions are necessary to assure consistency of use of certain terms. These are indicated below.

Element of information.[2] Information can be categorized in various ways. Elements, units, or chunks of information refer to discrete segments of the total information relevant to the accomplishment of a task. An information element is the smallest unit of task-required information and would loose its identity and meaning with respect to the

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[2]This definition is based on that provided in Auerbach Corporation, *DOD User Needs Study*, Phase I-Vol. I (AD-615501), May 14, 1965 (Philadelphia: Auerbach Corporation, 1965), Appendix D for a "chunk" of information.

task if segmented further. An information element can be categorized in terms of whether it is sought by the problem solver or arrives in a random manner. At some point in the decision process an element is either rejected or becomes an "input" to the decision. The information universe in the context of study refers to that information which is not contained in the mind of the problem solver. The information element is broadly defined as any stimulus considered by the individual for utilization in the solution of a task. These stimuli can be oral and visual as well as written.

Information-processing. Information-processing relative to task oriented problem solving refers to the total path taken by an information element ranging from initial search through the conclusion of a task. The process can be divided into the four phases or stages of search, receipt, evaluation, and integration.

Individual problem solver. The individuals of interest are those actually carrying out tasks in contrast to those responsible for the accomplishment of technical tasks. Information inputs to task solutions may be provided by others since other individuals form a part of the total information universe available to a given problem solver.

Task. The tasks or problem situations to be considered in the study must involve a time span sufficient that they can be viewed in terms of a process leading to a solution rather than consisting of a problem identification and a relatively instantaneous decision. A basic premise is that on even relatively simple technical tasks, information-processing occurs.

Individual's image state for task. Ammerman suggests that all of the accumulated, organized knowledge that an individual has about himself and his environment can be thought of as his image state.[3] This state includes everything the individual has learned including his values as well as facts. It is organized by whatever concepts, images, or relations the individual has at his command. It seems conceptually useful to define a similar image state for a particular task which would involve a particular subset of the individual's total image state. A stimulus in the form of a task to be solved would activate certain elements of an individual's store of knowledge defined as his image state for the particular task.

Variable Domains

The selection of possible explanatory variables for individual information-processing is open to a wide range of possibilities. For a given environment these variables can be identified as belonging to the domain of the individual, the domain of the problem or task, and the domain occupied by variables characterizing the interaction of an individual and a task.

The analytical focus of the study is that of considering information-processing behavior as dependent upon variables relating to the individual, task, and interaction domains. A concept that is central to the proposed research is that of the search for information, receipt of elements of information, and the processing of these task related elements to the conclusion of the decision process of the task. Figure 3 indicates the variable domains pertinent to the study and the assumed direction of influence.

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[3] Harry L. Ammerman, A Model of Junior Officer Jobs for Use in Developing Task Inventories, Technical Report 65-10 (Alexandra, Va.: George Washington University, Human Resources Research Office, November, 1965), p.13.

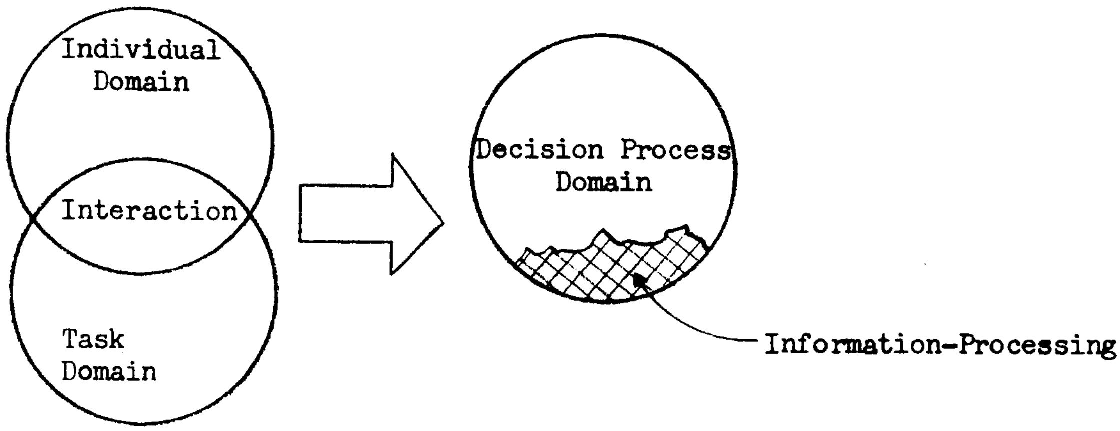

Figure 3 — Domains of Study Variables

VARIABLE SYSTEM

Certain analytical dimensions of the study were discussed in the previous section. These guidelines provide the conceptual frame of reference for developing a variable system of individual information-processing. An extensive number of variable possibilities exists within the variable domains identified earlier in the chapter.

The formulation of an all inclusive variable system is not an objective of this exploratory effort. Rather, the intent is to seek out from the appropriate variable domains, a selective group of those candidates which appear to be potential correlates of individual information-processing behavior. A delicate balance exists between the formulation of a sufficient, meaningful set of explanatory and dependent variables on the one hand—while on the other hand restricting the variable system to an appropriate size such that analysis will not be overly complex. A key influence on these selections is the degree to which a potential explanatory variable has been found through previous research to impinge upon the decision process domain. Additionally, where prior research foundations are not available, potential variable linkages that appear logical in terms of the desired variable system are indicated.

The sequence of variable identification moves from the information-processing domain to the individual, task, and interaction domains. The variable candidates are then assembled in a conceptual variable system. At that point certain pertinent characteristics of the conceptualization are discussed.

Information-Processing Domain

The relationship of information-processing as an important dimension of a decision process was established in Chapter 2. The task at hand is the identification of those variables which may be helpful in characterizing information-processing activities of individuals.

It seems appropriate to consider information-processing variables in terms of the following sequential phases:

1. Search. This refers to action taken by the problem solver to locate information pertinent to his task.

2. Receipt. Information resulting from search action (or random arrival) is received by the problem solver. This information can be categorized according to various classification schemes.

3. Evaluation. Each information element is evaluated by the individual with respect to the task at hand. The result of evaluation is either acceptance or rejection.

4. Integration. The final phase involves the integration (use) of an information element in the decision-process. The line between evaluation and integration effort may at times be difficult to identify.

The breakdown of information-processing into these phases involves the risks inherent in attempting to characterize any dynamic, continuous process as a sequence of discrete phases or steps. Nevertheless, such an approach seems inescapable in terms of the need to get at the structure and interrelationships of the total process.

Morasky indicates that information-processing consists of selection, assessment, classification or integration, and the reproduction of newly acquired information.[4] These efforts are quite similar to the information-processing phases discussed above.

The information element provides a basic unit of analysis of the study which allows a micro-viewpoint of information-processing. Information can be classified by individual elements upon receipt by the individual. This identity can be maintained through subsequent stages to completion of a task. The use of such a basic analytical element should overcome most of the problems involved in using a stage approach to a process.

<u>Search phase</u>. Two dimensions seem sufficient and appropriate to characterize the search phase. These are <u>sources sought</u> and <u>search investment</u>.

All possible sources of information can be grouped into two subsets associated with those sources in the <u>internal</u> environment and those contained in the <u>external</u> environment of the individual. The internal environment is defined as that related to the organization of which the individual is a member, such as the firm. Examples of sources are a supervisor, colleague, organized information system, and a manufacturer or supplier.

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[4]Letter from Robert Morasky, Assistant Psychologist, Reading Improvement Service, The University of Michigan, Ann Arbor, Mich., December 28, 1966.

Ammerman outlines four general types of information gathering activities divided into communications from people and those discernable from equipment or system:[5]

1. Seeking and/or receiving information from people via verbal communications.

2. Observing the manner in which individuals accomplish tasks.

3. Observing the results of performance by others without actively participating.

4. Accomplishing a task and then observing the results of the performance.

Sources sought is a relevant variable for mapping the portions of the information universe activated for a particular task. It is important to know the particular intelligence structure used for a task. The objective is to identify the variation and frequency of sources contacted for a particular task during all phases of the task. As discussed in Chapter 2, models of the decision-process typically characterize information search as an early phase of the decision-process. In this study search action during all phases of the decision process is of interest. Sources sought can be categorized by a descriptive classification scheme subdivided into internal and external sources.

Search investment provides an additional dimension of the search for information which allows comparison of the use of a scarce resource such as time (or dollars) relative to each source sought. This variable is intended to reflect the time and/or cost involved in searching for information.

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[5]Ammerman, op. cit., p. 22.

Receipt phase. This phase concerns the receipt of information resulting from search action initiated by the individual, or alternatively information relevant to a particular task may randomly come to the individual's attention (for example, scanning a professional journal). At this stage information can be identified in terms of elements. The individual does not actually process information during the receipt phase. Rather, it provides an appropriate point in the process at which each information element can be identified according to certain descriptive classifications. This identification is useful in tracing the subsequent processing of each element through the evaluation and integration phases.

Information is not necessarily homogeneous. It can be categorized in various ways. Meister and Farr suggest that the most important distinction is between prescriptive and non-prescriptive information. They indicate that prescriptive information has a mandatory effect on decisions while the bulk of information is non-prescriptive in that acceptance of the implications of the information is not mandatory. In effect, prescriptive information serves as a constraint upon the use of non-prescriptive information.[6]

For analytical purposes it seems appropriate to identify the receipt of each information element as to its prescriptive or non-prescriptive nature and then to classify each in terms of the communication channel or media, type of element, and the timing and order of arrival with respect to the decision process.

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[6]David Meister and Donald E. Farr, Development of Tests to Measure the Utilization of Human Factors Information by Designers (U), (Canoga Park, Calif.: Bunker-Ramo Corporation, December 16, 1965), p. 131.

The Auerbach study provides a convenient classification system for media and type of element.[7] Examples of media are oral contacts, brochures, computer printouts, texts, correspondence, etc. Categories descriptive of element type include raw-data, design techniques, concepts, and experimental processes. The timing and order-of-arrival dimensions of the receipt phase concern the establishment of time and relative order of arrival of each information element for a particular task.

Evaluation phase. This phase concerns the evaluation of an information element to determine whether to accept or reject it for integration into the decision. Both rejected as well as accepted elements are relevant to understanding individual information-processing in decision-making. Four characteristics of the evaluation phase appear to be appropriate dimensions to describe the process of evaluating an information element: (1) competency and reliability, (2) relevance to task, (3) degree of conflict with the individual's image state for the task, and (4) evaluation investment.

A low degree of relevancy of an information element to a particular task seems to be an adequate basis for rejection. However, using only this variable to describe the evaluation phase may tend to over-simplify the process. Meister and Farr imply this when they indicate that "the utility of an input [information element] must at least balance the cost before the input will be accepted."[8]

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[7] Auerbach Corporation, DOD User Needs Study, Phase I-Vol. II (AD-615502), May 14, 1965 (Philadelphia: Auerbach Corporation, 1965), pp. 6-26 and pp. 6-30.

[8] Meister and Farr, op. cit., p. 130.

For example, if a relatively high evaluation investment is required before determining the relevance of a particular element it seems reasonable that for certain individual and/or task characteristics rejection might be expected to occur without determining relevancy or alternatively it might be retained after determining relatively low relevancy. It seems necessary, without evidence to the contrary, to consider the evaluation phase in terms of more than a single dimension (relevancy).

The competency and reliability of a particular element refers to an evaluation based on the origin of the information. For example, an information element that arrives from an origin which is considered relatively unreliable by the individual might be less likely to be accepted than another, all other things equal. Evaluation resulting in a determination of questionable accuracy of an information element is reflected in the characteristic, competency and reliability of information.

The relevance of an element to a particular task was discussed above. This is certainly a significant dimension of the evaluation phase. In many cases, given an adequate determination of relevance, the characteristic will probably serve as a sufficient basis for acceptance or rejection.

It seems reasonable to expect that the set of information elements for a particular task will individually reflect various degrees of conflict with the individual's image state for the task. Further, it would be expected that since elements arrive throughout the decision process that the image state at the time of receipt of each element will not be the same. A situation to illustrate the case might involve the receipt of an element with high competency and reliability and high relevance but also with high conflict with a relatively certain image state. Thus, the variable, image state conflict, in a situation such as this would be an important dimension of the evaluation phase of information-processing. To not consider the characteristic without further evidence to the contrary seems inappropriate.

Evaluation investment concerns the time and/or dollars necessary to reach the point of an accept or reject decision. It is expected that this characteristic will vary by element and should be identified for each element.

Integration phase. This is the final phase of individual information-processing. Integration is performed on all accepted information elements. However, it is possible that an accepted element may be rejected during the integration phase. This phase ranges from acceptance of a particular element to the time that the task is completed. Integration of subsequent elements with respect to a given element may bring about the ultimate rejection of the element. The set of accepted elements plays a continuing role in task solutions up to the conclusion of the task.[9] An appropriate group of integration dimensions must reflect the dynamic nature of elements moving through the phase.

Three variables seem useful for describing elements in the integration phase: (1) degree of image state change, (2) contribution to result, and (3) integration investment. The latter is similar to the investment characteristics discussed with respect to previous stages. Investment can be viewed in terms of time span, cost, or man-hours.

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[9] Ibid., p. 131.

Integration of a particular element would be expected to influence an individual's image state for a particular task from the time of acceptance through to completion of the task. The degree of influence of a particular element on image state change during this phase suggests a relevant dimension of information processing.

An element's influence on the degree of image state change may not reflect the element's contribution to the final result of a particular task. Accordingly, it seems appropriate that each element be ranked, rated, or grouped according to its contribution to the task result. It is important to note that there may be a relatively high interaction between an element's degree of image state change and its contribution to the task result.

Meister and Farr describe an information-processing phenomenon which seems analogous to a change in image state:

> "Once information has been applied to a design solution it becomes part of the body of information describing the system and continues to be used by the designer but in a different manner. Such information will continue to form part of new inputs and may influence the analysis of any new inputs elicited by later problems."[10]

This completes the identification of dependent information-processing variables. The twelve variables are listed in Figure 4 by phase (they are also denoted by the symbol I_i):

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[10] *Ibid.*, p. 131.

SEARCH PHASE

I_1 - Sources Sought

I_2 - Search Investment

RECEIPT PHASE

I_3 - Channel/Media

I_4 - Type

I_5 - Timing/Order of Arrival

EVALUATION PHASE

I_6 - Competency/Reliability

I_7 - Relevance to Task

I_8 - Image State Conflict

I_9 - Evaluation Investment

INTEGRATION PHASE

I_{10} - Image State Change

I_{11} - Contribution to Result

I_{12} - Integration Investment

Figure 4 — Information-Processing Variables

The next stage in the development of this conceptual framework of individual information-processing concerns the identification of appropriate variables in the domains of the <u>individual</u>, the <u>task</u> and individual/task <u>interaction</u>.

Individual Domain

The possibilities for selection of variables from within the domain of the individual can be grouped as to whether they relate to idiosyncratic, intellective, cognitive, and personality aspects of the individual. No attempt has been made to seek out an all inclusive set of variables within the individual domain for use as possible correlates of individual information-processing. An effort has been directed toward the selection of a meaningful group of variables (with an indicated potential linkage to the information-processing domain) representing each of the aspects of the individual. It is important to note that these individual dimensions are referred to as independent of a particular task.

Idiosyncratic variables. The range of possible variables relating to idiosyncratic aspects of the individual is almost unlimited. Factors such as age, sex, education, experience, job level, job type, and number of people supervised are indicative of the range of possibilities. For a given population certain characteristics will vary while others remain relatively constant. The nature of the present study suggests years of experience and job performance as relevant dimensions of variation. Experience is referred to as professional job related experience. In most cases age is indirectly reflected in years of experience.

Job performance appears to be a meaningful dimension that could influence an individual's information-processing behavior. Allen and Andrien suggest that a relationship exists between group performance and information gathering.[11] It seems appropriate to define job performance on a general basis rather than for a specific task.

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[11]Thomas J. Allen and Maurice P. Andrien Jr., Time Allocation Among Three Technical Information Channels by R and D Engineers (Cambridge,

The selection of participants for the study will attempt to hold constant various other idiosyncratic dimensions of the individual. For example, only male subjects will be included.

Intellective variables. As indicated in Chapter 2 research findings concerning the intellective correlates of decision-making are quite limited. However, in view of the exploratory nature of the study and particular focus on individual information-processing, measures of verbal and quantitative aptitude will be included.

Cognitive variables. An individual's cognitive processes concern the means by which he achieves, retains, and transforms information.[12] Two cognitive dimensions appear to be promising as possible correlates of individual information-processing: (1) risk-taking propensity and (2) information-processing efficiency.

Kogan and Wallach have distinguished between the kinds of risk involved in cognitive processes and those involved in decision-making. They observe that:

> "The cognitive-judgmental tasks we have considered ostensibly deal with problem-solving performance; the risk element is more or less covert, emerging implicitly in terms of the strategy the subject employs in meeting overt task requirements. Actually, the subject often was not told whether he had been correct or incorrect. Thus, the risk element, if present at all, is based on the subject's assessment of his own tolerance limits for error. Decision-making procedures, by contrast, introduce risk explicitly, in terms of the subject's assessment of probabilities of success and failure and their corresponding utilities preparatory to making a choice. The

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Mass.: Massachusetts Institute of Technology, Alfred P. Sloan School of Management, August, 1965), p. 6.

[12] Jerome S. Bruner, Jacqueline J. Goodnow, and George A. Austin, A Study of Thinking (New York: John Wiley & Sons, Inc., 1956), p. vii.

risk element is clearly explicit whether the decisions occur in a hypothetical success-failure context or in a situation involving direct gain-loss consequences."[13]

An individual's risk-taking propensity (of the cognitive-judgmental type) seems to be an appropriate variable for inclusion in the study as a potential correlate of individual information-processing. Certainly, risk-taking propensity can conceivably influence a number of information-processing characteristics. An operational difficulty concerning the variable is that of achieving a measure of comparison among individuals relative to their risk-taking propensities.

An individual's information-processing efficiency offers a potential cognitive dimension. This variable along with the concept, "information overload," was discussed in Chapter 2. Information-processing efficiency is defined in the present study as the efficiency of an individual in assimilating information. If the information inputs on a given task are held constant (at a sufficient quantity level) then, for a given set of individuals, information-processing efficiency can be measured in terms of the variation in decision-making performance by each individual.

Personality variables. There are several reasons for not including personality variables in this conceptual formulation. In terms of a broad definition of personality processes (abilities, beliefs, attitudes, and motives) certain personality dimensions have already been identified as possible correlates of information-processing.

Personality correlates of decision-making are by no means clearly indicated in the literature. Their possible impingement upon the

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[13]Nathan Kogan and Michael A. Wallach, Risk Taking: A Study in Cognition and Personality (New York: Holt, Rinehart and Winston, 1964), p. 5.

information-processing domain is even less certain. Very little in the way of prior research is available to guide the selection of appropriate personality variables. Thus, a great deal of uncertainty prevails concerning the impact of personality processes on decision-making in general and on individual information-processing in particular.

The possibility of a relationship between personality processes and information-processing cannot be completely eliminated. However, in view of the current state of knowledge concerning the area, the analytical complexities involved, the indication of potentially stronger influences on the part of other correlates, the already extensive system of variables in this conceptual framework, and the exploratory nature of the study, it seems reasonable to assume that personality variables do not impinge upon the information-processing domain.

As a partial proxy for the personality dimension risk-taking propensity may prove useful as indicated in Chapter 2. In view of this along with the considerations discussed above, no personality variables are included in this conceptual formulation.

Task Domain

The tasks of central interest in this study are those at the technical level. These tasks concern the acquisition and utilization of technical knowledge by individuals in the carrying out of operational actions. (See study assumptions earlier in the chapter.)

Task variables are considered independent of the individual. Variables that involve individual/task interaction are considered later in the chapter. Decision process stage is not utilized directly as a variable; rather, it is used as a frame of reference with respect to the total variable system. For example, certain characteristics are of interest before a task is initiated. Others relate to the task over time (during the process). Still others focus on the outcome of the task.

Variables occupying the task domain can be grouped in various ways. For the purposes of this research effort task variables are placed in one of two broad areas: (1) those aspects of the task which are of a situational nature and (2) those characteristics that are of an evaluational or abstract orientation. These two groupings are similar to the decision classifications discussed in Chapter 2.

Situational variables. Numerous situational dimensions could be considered. Four dimensions of variation have been selected for inclusion in the study. These are: (1) the scientific or technical field of the task; (2) the major output of the task; (3) the task function; and (4) the time span of the task. These four situational task dimensions seem appropriate as descriptive elements of the information-processing model. Depending upon a particular environment of interest it is likely that not all characteristics will reflect the same degree of variation.

The Auerbach study utilized the scientific and technical field of a task as a descriptive dimension.[14] Examples of field categories include mathematics, electronics, geophysics, and medical sciences. Subcategories can be identified within each major area.

The major output of a task relates to whether the result is a finding, a recommendation, a decision, or some other type of output.[15] The intent

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[14] Auerbach Corporation, DOD User Needs Study, Phase I-Vol. I (AD-615501), May 14, 1965 (Philadelphia: Auerbach Corporation, 1965).

[15] Ibid., pp. B13-B14.

is to describe the form of the output of a given task. The proposed Bunker-Ramo study suggests that work output be identified as formal (design product, analysis, experimental data, or plan of action) or informal (memoranda, notes, or interpersonal communication).[16]

The task function refers to the level of the major output which can range from research to manufacturing.[17] The Bunker-Ramo study breaks down project (task) function into research, development, testing, and analytic (e.g., proposals).[18]

Trull has identified the time span of a decision as a relevant task characteristic.[19] The time span of a task can be defined in terms of the elapsed time between receipt of the task by the individual and its conclusion.

Evaluational. Three evaluational task variables have been selected as possible correlates of individual information-processing. They are: (1) the precision with which the task is defined; (2) the scope and complexity of the task; and (3) the degree of success of the results of the problem solving effort.

The precision with which a task is defined suggests an important dimension of variation. Included in the task definition are applicable

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[16] The Bunker-Ramo Corporation, Proposal for the Study of Information Utilization in the Industrial Environment, No. 5612-012-6U1 (Canoga Park, Calif.: The Bunker-Ramo Corporation, Defense Systems Division, August, 1966), pp. 16-17.

[17] Auerbach, op. cit., p. B-11.

[18] Bunker-Ramo, op. cit., p. 14.

[19] Samuel G. Trull, "Some Factors Involved in Determining Total Decision Success," Management Science, XII (February, 1966), p. B-271.

task objectives and constraints—the standards by which information elements and solutions are evaluated. It seems reasonable that the degree of precision with which the task is defined is a relevant task characteristic. It is not expected that the variable will remain constant during the decision process.

Scope and complexity concern the difficulty of attaining a solution to a particular task. As discussed in Chapter 2 Simon's continuum ranging from highly programmed tasks at one end to highly unprogrammed (heuristic) decisions at the other end provides a basis for viewing scope and complexity.[20] This continuum may reflect the relative importance of a task. Certainly scope and complexity is a task characteristic that might be expected to influence individual information-processing.

A possible relationship between task results and information-processing in terms of the degree of success appears worthy of investigation. Allen and Andrien included this variable in their study.[21] Results should be evaluated in terms of task objectives and constraints. Relatively successful results are reflected in terms of the degree to which positive statements can be made regarding a task solution.

Individual/Task Interaction Domain

There are certain variables related to both the individual and a particular task which need to be considered in the development of a conceptual model of individual information-processing. Four variables are considered: (1) the individual's image state at the outset of a

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[20]Herbert Simon, The New Science of Management Decision (New York: Harper & Brothers Publishers, 1960), p. 5.

[21]Allen and Andrien, op. cit.

task; (2) the individual's degree of uncertainty concerning the outcome of the task; (3) individual's interest in task; and (4) the ordinal position of the task with respect to the other tasks being handled by the individual.

Information theory as discussed in Chapter 2 offers a potentially useful concept for viewing an individual's image state with respect to a particular task. Drawing from the theory it might be expected that if an individual's image state concerning a task is perfect then no information (outside of the mind of the individual) would be processed. Starting from a less than perfect image state, change in the state would be expected during the decision process.

An individual's degree of uncertainty regarding a task outcome provides an interaction dimension of possible relevance to this study. This dimension relates to the individual's assessment of the probability of success relative to making a decision. It is analogous to the Kogan and Wallach _explicit_ element of risk discussed earlier in the chapter.[22]

While an individual's image state and his uncertainty relative to the outcome of a task seem closely related it seems reasonable to distinguish between the two variables. It may be found in certain instances that the two are highly correlated.

A variable reflecting individual task interest appears relevant to this study. Morris has defined "intrinsic interest" as the degree to which a task is in and of itself interesting, motivating, or attractive

[22]Kogan and Wallach, _op. cit._, p. 5.

to group members.[23] He utilized a ranking scheme ranging from low to high interest for a given task. Kogan and Wallach refer to an individual's "ego-involvement" in a decision which appears related to task interest.[24]

The ordinal position of a task is referred to as the position (relative to receipt of the task) of a given task in terms of an individual's set of tasks. As tasks are added and completed ordinal position will change for a particular task. The variable appears potentially relevant as a correlate of individual information-processing.

Variable System

This development of a variable system of individual information-processing has moved forward along two channels. The first involves the conceptualization of information-processing as consisting of four stages or phases. Each stage has certain dimensions characterized by variables. The complete set of variables for all stages comprises the dependent variable system of the study.

The second main stream of development has provided a carefully selected set of independent variables which appear to be potentially useful as correlates of individual information-processing behavior. Wherever possible independent as well as dependent variables have been linked with existing research foundations. In other cases logic and analysis have guided the selection of variables.

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[23]Charles G. Morris, Effects of Task Characteristics on Group Process, Technical Report No. 2, AFOSR-65-1519 (Urbana, Ill.: University of Illinois, Department of Psychology, July, 1965), p. 20.

[24]Kogan and Wallach, op. cit., p. 6.

Certain of the variable building blocks have been utilized in other research efforts along similar lines to the present study. However, the particular combination of variables in the present study is unique. The complete set of variables can be placed into an organized framework or variable system. This combination of variable building blocks is shown in Figure 5.

The important characteristics of the variable system need to be specified. Consider the existence of a task or problem requiring a solution by an individual. Using an information-processing viewpoint the individual searches for information, receives information elements, evaluates them, and integrates those accepted elements into the task solution. The process is not necessarily sequential. Orderly processing of each element may not occur. An element may wait at a certain stage while the individual moves back to a previous stage to process another element. The important consideration is that each information element maintain its identity throughout the processing stages. In this context the information element provides a meaningful unit of analysis.

The iterative nature of the decision process must be recognized. The information element as a basic unit of analysis provides a way to allow for recycling and doubling back in an individual's problem solving process. The information element gains its identity at the receipt stage and maintains it through to completion of the task.

Information-processing is viewed as an integral part of the decision process. For given problem situations (tasks) facing the individual, analysis via the information-processing variable system can span each decision process situation from recognition of the task to the final outcome.

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INDEPENDENT CHARACTERISTICS

INDIVIDUAL

Idiosyncratic:
- P_1 - Experience
- P_2 - Job Performance

Intellective:
- P_3 - Aptitude (Verbal & Quantitative)

Cognitive:
- P_4 - Risk-Taking Propensity
- P_5 - Information-Processing Efficiency

TASK

Situational:
- T_1 - Field
- T_2 - Major Output
- T_3 - Task Function
- T_4 - Time Span

Evaluational:
- T_5 - Precision of Definition
- T_6 - Scope and Complexity
- T_7 - Results

INDIVIDUAL/TASK

- J_1 - Image State for Task
- J_2 - Interest in Task
- J_3 - Uncertainty of Outcome
- J_4 - Ordinal Position of Task

DEPENDENT CHARACTERISTICS

TASK RECOGNITION

↓

SEARCH FOR INFORMATION

- I_1 - Sources Sought
- I_2 - Search Investment

↓

RECEIPT OF INFORMATION ELEMENTS

- I_3 - Channel/Media
- I_4 - Type
- I_5 - Timing/Order of Arrival

↓

EVALUATION

- I_6 - Competency/Reliability
- I_7 - Relevance to Task
- I_8 - Image State Conflict
- I_9 - Evaluation Investment

↓

INTEGRATION

- I_{10} - Image State Change
- I_{11} - Contribution to Result
- I_{12} - Integration Investment

↓

COMPLETION OF TASK

Figure 5 — Information-Processing Variable System

The framework is flexible to the degree that improvements can be made as the study proceeds. The variable system lends itself to a process type of analysis. It links together the central dimensions of the study—the individual, the task, and information-processing.

Those variables relating to the individual, the task, and the individual/task provide the set of characteristics to be utilized in attempting to gain a better description of individual task oriented information-processing. The complete system provides a useful framework for identifying potentially important relationships and for developing an appropriate methodology for empirical analysis.

RELATIONSHIPS TO BE INVESTIGATED

This study is exploratory. The intent of the research effort is to point out possible relationships rather than to make rigorous tests of carefully formulated hypotheses. A strategy which seems logical in terms of the nature of the study is to identify, rather specifically, the relationships of interest, using these to guide the collection and analysis of data.

The analytical framework shown in Figure 5 suggests three areas within which relationships can be identified to aid in refining the model and to better describe the dimensions of individual information-processing in the accomplishment of tasks. Relationships may be grouped according to those associated with:

1. the information search stage,
2. the evaluation stage,
3. the integration stage.

The receipt stage is a classification point for establishing the dimensions of each information element for the remainder of the decision process. Accordingly, relationships will not be investigated for the receipt stage.

In the context of the variable system that has been formulated, two main sets of relationships are of interest. The first concerns the over-all impact of the group of independent variables on the sets of dependent variables in each of the phases of information-processing. The second area of interest concerns the degree (and direction) of influence of each independent variable on the various sets of dependent variables.

An assumed direction of influence of the variables in the study has been indicated in terms of the identification of independent and dependent variables. The three groups of independent variables relate to the individual, the task, and individual/task interaction. These variables are believed to be possible correlates of individual information-processing.

In reference to Figure 6, four specific relationships are of interest:

1. The aggregate influence of the complete set of independent variables on the total group of dependent variables.
2. The total impact of the set of independent variables on each of the search, evaluation, and integration phase variables sets.
3. The strength of influence of each independent variable.
4. The direction of influence of each independent variable.

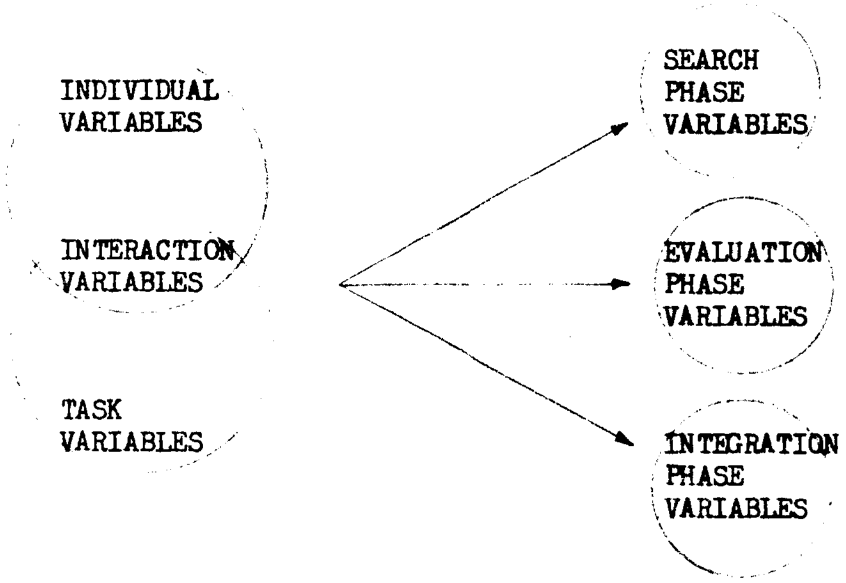

Figure 6 — Study Variable Linkages

The aggregate influence of the complete group of independent variables on the dependent set refers to the strength of the combined relationship between the two groups of variables. Interest is in terms of the degree to which the combined exploratory variables are related to the total set of dependent variables.

In a similar context, the impact (influence) of the explanatory set on the subset of dependent variables in each of the three phases is also of interest. For example, what sort of a relationship exists between the group of variables pertaining to the individual, the task, and their interaction—and the search phase variables, Sources Sought (I_1) and Search Investment (I_2)?

A determination of the strength and direction of influence of each independent variable can provide guidelines concerning the importance of the role played by each element in the total variable system. For example, it would be of interest to find (for a given environment) that

Risk-Taking Propensity (P_4) is relatively more important in describing information search behavior (search phase variables) than is Information-Processing Efficiency (P_5). In a similar context, the direction of influence (i.e. variation in direct proportion or alternatively in inverse proportion) of each independent variable is important.

SUMMARY

In this chapter a conceptual framework for analysis of individual, task oriented, information-processing has been developed. The model consists of several independent variables believed to be potential correlates of information-processing variables. These variables have been selected from the domains of the individual, the task, and their interaction.

The variables do not reflect an exhaustive, all inclusive attempt to identify all possible independent and dependent variables. However, they do appear to be likely candidates for empirical investigation.

Several relationships of interest have been identified. These possible relationships relate to the aggregate impact of independent variables on the dependent set as well as to the role of each variable in the system. These relationships provide guidelines for developing an appropriate methodology for empirical analysis. This is accomplished in Chapter 4.

CHAPTER 4

RESEARCH METHODOLOGY

The conceptual framework developed in Chapter 3 provides the structure within which relationships of interest to the study can be investigated. In this chapter the research methodology utilized to investigate these relationships is presented. The research site selected for the study is discussed along with the subjects and tasks included in the study. The measurement of each independent and dependent variable is described in detail. The statistical method of analysis of data is outlined.

RESEARCH SITE

Environment of Interest

The environment of interest in the investigation is that within which individual information-processing takes place in the accomplishment of technical tasks. Technical problem solving can be viewed as a processing system through which information inputs are transformed into new information. In this context the individual scientist or engineer is an information processor. He obtains, evaluates, utilizes, transforms, and generates information.[1]

In view of the exploratory nature of the study, depth of investigation is of primary interest. Information-processing variables and their

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[1]Auerbach Corporation, Interview Guide Handbook (Philadelphia: Auerbach Corporation, July 2, 1964), preface.

possible correlates provide the main focus of the effort. There is no intent to generalize in any quantitative sense about the findings of the research. There are a number of reasons for confining this type of investigation to a single organization. A discussion of these factors follows.

The on-going, dynamic aspects of individual information-processing are central to the research effort. Interest is in the intricacies of task-oriented information-processing from the recognition of a task through to its completion. A depth study of variables and their interrelationships is more important than obtaining a large number of observations of particular variables. The financial and time limitations of the study prevent both depth and breadth of data collection.

In view of the dimensions of the study as well as its process orientation, it is important for the researcher to gain a close and continuing relationship with the subjects by utilizing multiple interviews, structured diaries, questionnaires, observations, and monitoring of tasks including related records and paper work associated with each subject and task.

Full cooperation on the part of the study participants, as well as an understanding of the nature and depth of information required for the study, are critical in achieving the objectives of the research. Data collection requirements are extensive and time consuming. The success of the effort is highly dependent upon the researcher being able to obtain, in effect, a play-by-play description of information-processing activities.

The time required from each study participant is extensive. The organization involved must be willing and able to make this time available. It is also important that the tasks involved in the study reflect some degree of homogeneity.

Finally, it is necessary that the various environmental influences surrounding the research site be held constant. This would be extremely difficult if more than one organization were utilized.

The Aerospace Research Applications Center (ARAC) at Indiana University provides a research site which satisfies these requirements reasonably well. ARAC is a cooperative program on the part of the National Aeronautics and Space Administration, Indiana University, and industry. The Center's primary mission is to aid and accelerate the transfer of technology from government research and development results into commercial applications.[2] Transfer concepts and mechanisms have been formulated, developed, and tested in industrial firms utilizing various man-machine system combinations.

One of the major efforts of the Center involves the accomplishment of technical tasks requested at random from over 60 industrial firms representing a broad cross section of sizes and types of firms. These tasks range from carefully defined, specific problems, such as the heat transfer coefficient of a particular material, to broad "state-of-the-art" type tasks, such as identifying available information on magnetic film devices.

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[2]See David W. Cravens, "Information Systems for Technology Transfer," Science, Technology, and Marketing, ed. Raymond M. Haas (Chicago: American Marketing Association, 1966), pp. 47-60 for a detailed discussion of ARAC's efforts relative to the generation, communication, and transfer of technology.

These tasks, while of an information gathering nature, are significantly more than literature searches. Each staff engineer or scientist is faced with finding a solution to the problem at hand. He is, in effect, a problem solver at the disposal of the particular technical person in a given firm.[3] The staff engineer seeks information from a variety of sources (both internal and external) in attempting to solve a problem. Careful assessment and evaluation of information are accomplished. While ARAC's technical staff is made up almost entirely of graduate students, these people are competent professionals operating within a technical environment.

Approximately 20 problems arrive randomly from the Center's participating companies each week. The tasks typically represent sub-problems of larger tasks such as research and development projects. Considering the time span and scope of complete projects and programs (some lasting several years) it is necessary to restrict this study to identifiable tasks or sub-units of larger projects. Such tasks are provided by the problems handled by ARAC.

There were several reasons for selecting this organization as a research site:

1. Meaningful technical tasks of reasonable time span are provided. Tasks arrive on a random basis from a rather extensive population.

2. There is a certain similarity in the nature of the tasks yet appropriate variation is reflected for the variables of primary interest. The desired characteristics are available.

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[3]A somewhat similar use of ARAC staff engineers for dissertation research is discussed in Ralph H. Sprague, Jr., _A Comparison of Systems for Selectively Disseminating Information_, Indiana Business Report No. 38 (Bloomington, Ind.: Graduate School of Business, Bureau of Business Research, 1965), p. 32.

3. An information-processing emphasis is inherent in the tasks offering an extensive base of data relative to each task.

4. The staff technical people should provide appropriate variation concerning the individual characteristics of interest.

5. The site provides the researcher the many advantages of a quasi-controlled laboratory experiment and yet overcomes many of the limitations of experimental studies involving college students.

Subjects of the Study

Eighteen male subjects were utilized in the study. The subjects were staff engineers and scientists employed by ARAC while pursuing additional degrees in business administration, law, and science.

Each individual had a work commitment of 24 hours a week for which he received $360 a month. All subjects had bachelors degrees in science or engineering. Fourteen were working on Masters Degrees in Business Administration. Three men were pursuing law degrees and one graduate work in mathematics.

The subjects provided a somewhat abstract representation of technical problem solvers in industrial firms. However, there were several important reasons for selecting these individuals for the study. First, they served as reasonable proxies for technical problem solvers in industrial firms. Each had a technical education and professional experience. The nature of their ARAC work responsibilities required technical competence. The tasks were related to industrial technical problems.

Use of these individuals in the study provided an environment which could be expected to remain relatively constant during the course of the research investigation. This environment was not unlike that of an industrial organization. The combined responsibilities of graduate studies and work as ARAC staff technical people provided an abundance of operating pressures and conflicts. Their work commitment was important for both financial and professional reasons, thus providing appropriate motivation to each subject.

Finally, the individuals of interest provided the researcher with convenient access to the collection of data required for an exploratory study of this type. The ready access of the site to the investigator also was expected to minimize nonresponse bias.

The subjects were similar in many respects. All had relatively high intellegence. Each was seeking an additional college degree. Similar criteria were considered in selecting them for employment including technical education and grades, industrial experience, communication skills, and maturity. Their job duties and responsibilities were essentially the same.

There can be certain problems involved in the use of graduate students as research study subjects. Applewhite comments on this as follows:

> "Statistically speaking, the most difficult problem here is inferring from a laboratory group of college students solving mathematical puzzles to a real organization solving economic problems. Not only is the population different, but so also is the task."[4]

The work environment of the subjects in the present study was believed to overcome (or at least reduce) these problems and at the same time provide a quasi-laboratory setting.

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[4]Philip B. Applewhite, Organizational Behavior (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1965), p. 55.

It was assumed that all subjects were sufficiently well adjusted to their jobs that the effects of "learning" were negligible. The Center's experience as reflected by its management has been that new staff scientists and engineers become oriented to their jobs rather quickly (within 60 days). All subjects had been employed by ARAC 60 days or longer. Additionally, the Center's management suggested that, to whatever degree learning curve effects might be present, these influences probably would be reflected in experience and job performance. Both of these variables were included in the study.

Tasks Included in the Study

The tasks included in the investigation were "retrospective search" requests received by ARAC from the Center's participating industrial firms. These tasks were similar in a number of respects. Each was an information seeking and processing situation, ranging from a very specific answer to a broad state-of-the-art type request. All tasks were of a scientific or technical nature. These tasks could be viewed as representing the information seeking stage of a decision process model. With the exception of state-of-the-art requests each task typically represented an element of a larger problem. All tasks were related to current industrial problems, ranging from production engineering to advanced research and development. The tasks involved multi-dimensional judgments in that various factors were considered in reaching a final decision.

The tasks arrived on a random basis. It is difficult to determine why technical people in industrial firms sent these requests to ARAC. Two factors appeared relevant. First, considering the nature of the Center's mission it seemed likely that individuals in the firms using the Center's services believed that relevant information concerning their problems might be found in the government scientific and technical information base. A second consideration was that the tasks submitted to ARAC probably represented elements of problems on which preliminary search of the "local" environment in the firm had yielded little or no information. In this context the tasks included in the study represented sub-problems of non-programmed tasks in that there were no simple procedures for achieving solutions. Or in simple terms, only the tough ones were submitted to ARAC.

The Center typically provided a two week processing time on all requests which tended to keep the magnitude of each request within a fairly stable and predictable time and effort range. Each task required the ARAC staff technical man to interpret what the company man's problem consisted of in terms of objectives and constraints. This interpretation usually involved analysis of an oral or written request coupled with subsequent interaction with the requestor.

Requests received from industrial firms were assigned by the Retrospective Search Service (RSS) supervisor to individual staff members giving first priority to the technical area involved in a particular task. For example, a plastics problem was typically assigned to a chemist or chemical engineer. This assignment also took into consideration industrial experience as well as educational background. Two additional factors which influenced the assignment were the current workload of staff members whose areas of professional specialization were relevant to the task, and the staff member's indicated past performance.

These factors suggested that a certain degree of homogeneity could be expected to exist across the tasks included in the study. At this point it is important to examine in what ways the tasks may have differed beyond those characteristics included in the study. Additionally, these characteristics need to be assessed in terms of their sensitivity as a possible source of unmeasured influence in the study.

Tasks may originate from the actual problem solver in a firm, or from an intermediary such as a librarian. The tasks may be initiated by individuals working in production through to advanced research and development. Only tasks submitted by actual problem solvers were included in the study. It was not anticipated that tasks originating from various phases of company operations would introduce a dimension of task variation that would influence individual information-processing within the study environment.

The nature of the information elements expected by the individual in the firm can range from information on a specific technique through to general information on some technical subject such as adhesives. It was assumed that, in view of the number of other similarities as well as the task dimensions measured in the study, the nature of information elements would not influence individual information-processing in the context of the study.

The firm submitting a request to the Center can vary significantly by size, product line, and technical capabilities, as well as in other ways. This dimension of variation is probably not as important with respect to task variation as a possible influence on individual information-processing as are other indicated variations. It was assumed that size and type of firm were not variables which would influence individual information-processing.

Approximately 20 tasks arrived each week and were assigned on the basis of area of specialization and work load to the eighteen staff engineers and scientists. Completion time for the tasks ranged from less than a week up to 60 days. Each involved less than five sources up to ten or more. A range of from less than 25 to over 100 information elements were processed for each task.

The basic unit of analysis for the study was the information element. On this basis a population of eighteen individuals handling two tasks each would involve nearly 3,000 information elements (assuming 75/task). Thus, around 40 tasks were expected to provide a reasonably large base of data and, at the same time, overcome the statistical problems inherent in a small sample.

The tasks included in the study were selected in two phases. Phase A and Phase B included 25 and 15 retrospective search tasks, respectively. Two phases were used to allow incorporation of data collection improvements during the course of the study as well as to prevent any one subject from receiving a large number of tasks on which detailed data was required. Also, it was necessary to hold the number of study tasks in process at a sufficiently manageable level for the investigator to maintain continuous surveillance.

It was assumed that the tasks arrived on a random basis. All tasks received during each phase were included in the study. The sample of 40 tasks was believed to be of sufficient size for statistical testing of the relationships of interest in the study. Each task required an estimated two to five hours of additional time on the part of the subject in order to provide the data required for the study. The financial and time constraints of the study prohibited the use of a sample size in excess of that utilized.

There was no reason to believe that the group of 40 tasks differed significantly from the regular stream of tasks received from ARAC. Those included in Phases A and B were two complete segments of the regular flow of tasks. In order to eliminate any possible subject/task bias, tasks were assigned in accordance with the Center's regular decision rules to the 18 subjects. In doing this there was no way to assure an even distribution of tasks among subjects. The actual task distribution is shown below:

Tasks	Subjects
1	6
2	5
3	5
4	1
5	1

DETAILS OF THE PROCEDURE

The objectives and character of the study were discussed in detail with the management group of ARAC in an attempt to identify potential measurement problems as well as to gain useful insights into measurement. Four tasks were monitored by the investigator before final development of measuring instruments. This was done to gain a detailed look at the intricacies of information-processing in the context of the tasks utilized in the study. These findings provided inputs to the design of measuring instruments for both the dependent and independent variables.

All measurements of independent and dependent variables were obtained from the subjects of the study except those related to the task variables and to the individual variable, job performance.

In advance of data collection the subjects were asked to participate in a study of individual information-processing and decision-making. They were told that certain information would be asked for relative to the details of their information-processing activity on retrospective searches. It was indicated that the time required for the study would be a part of their regular working hours.

The details of each dependent variable measurement were explained individually to each subject. The instruments to be utilized were discussed and questions were answered. Care was taken to focus these discussions on what each measurement involved in terms of the subject supplying the required data. Questions concerning "why" a particular measurement was included were delayed until the completion of the study, at which time each subject was given access to the complete results.

A basis was established for regular interaction between the subject and the investigator. Each subject was encouraged to seek answers to any questions that might develop during data collection. Regular contact was made with each subject to further preclude misunderstandings concerning the data required.

Throughout the data collection emphasis was placed on the fact that the study focus was on what actually was done by the subject in his information-processing activities. It was indicated that there were no "right" or "wrong" answers in the context of the study. Rather the interest was in describing in as great a detail as possible what actually happened.

In view of the process orientation of the study it is important to identify where in the decision process each variable was measured. This is indicated in Figure 7.

MEASUREMENT OF VARIABLES

Measurement Problems

Before discussing the details associated with the measurement of each variable it is appropriate to consider certain problems associated with measurement. Measurement is a technique utilized to superimpose a concept on an environment and to identify changes in the concept.[5] Rigby has identified three problems associated with measurement. First, the identification of a satisfactory scaling device. Second, the researcher must make certain that he is actually measuring what he thinks he is measuring. Third, the measurement must be made as accurately as possible and the degree of precision known.[6]

Measurement can be classified according to levels: nominal, ordinal, interval, and ratio. Each is briefly outlined below drawing from Siegel:[7]

Nominal or classificatory scale. This is measurement at its weakest or very primative level. Numbers (or other symbols) are used to classify an object, person, or characteristic. The scaling operation involves

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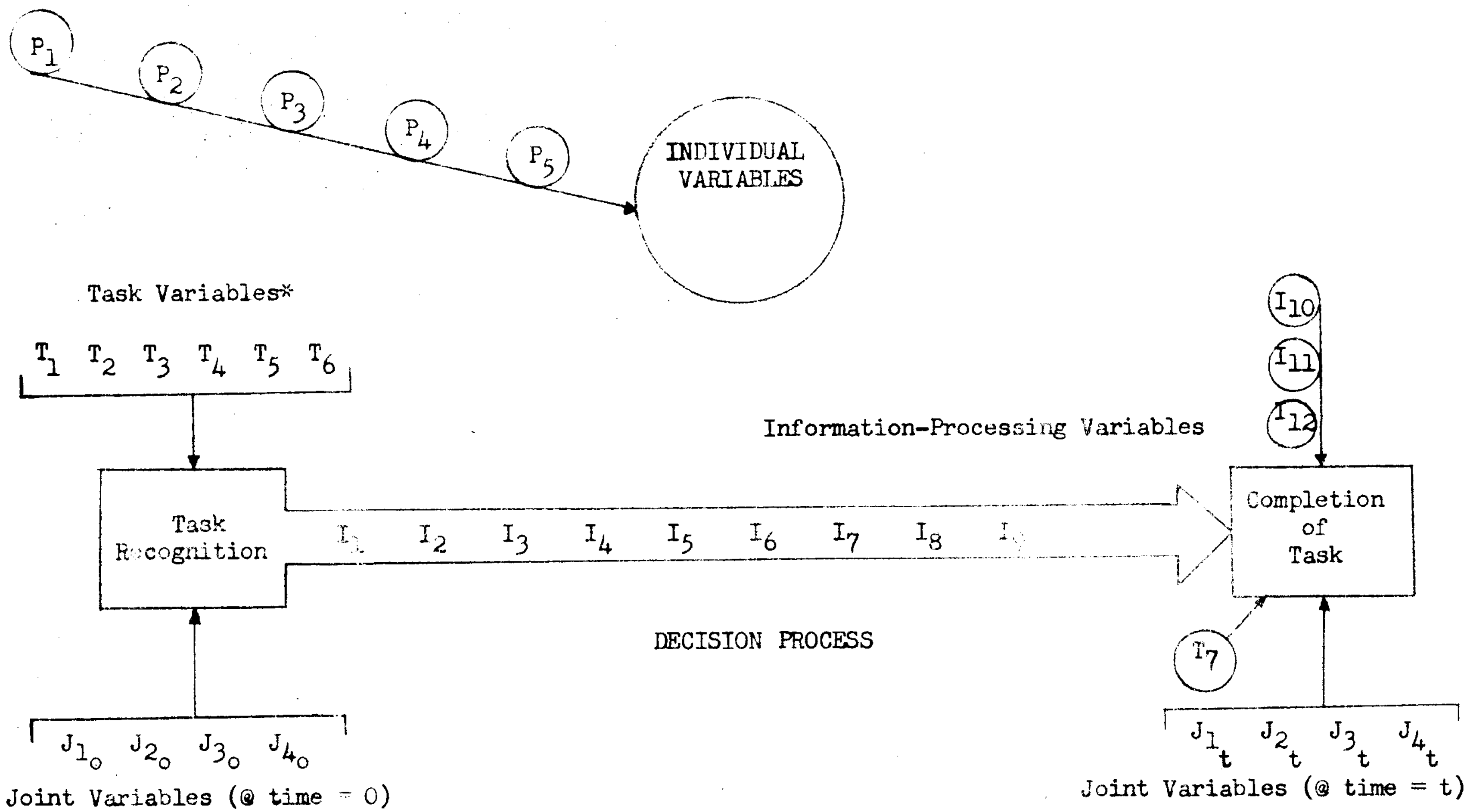
[5]Paul H. Rigby, Conceptual Foundations of Business Research (New York: John Wiley and Sons, Inc., 1965), p. 156.

[6]Ibid., p. 158.

[7]Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, Inc., 1956), pp. 22-29.



*Measurements of Task variables were obtained from the RSS Supervisor. All other measurements were obtained from the subjects of the study.

Figure 7 -- Time Span of Variable Measurement

partitioning of a given class into a set of mutually exclusive subclasses.

Ordinal or ranking scale. Measurement at this level allows objects to be ranked on a basis of comparison. In other words X is greater than Y. It is not known how much greater. If the relation "greater than" ($\succ$) holds for all pairs of classes then an ordinal scale exists. Variable measurements in the behavioral sciences are typically no stronger than ordinal.

Interval scale. Measurement according to this scale provides all of the characteristics of ordinal measurement with the additional characteristic that the distances between any two numbers on the scale are of known size. Thus, the measurement achieved is considerably stronger than via an ordinal scale.

Ratio scale. A ratio scale has all of the characteristics of an interval scale plus a true zero point as its origin. Here, the ratio of any two scale points is independent of the unit of measurement. Any statistical test can be utilized if ratio measurement has been accomplished.

Most of the measurements that were utilized in the study were either on an ordinal or interval scale.

The approach which was followed in the study was to develop a conceptual model of variables. This was accomplished in Chapter 3. During this conceptualization the actual measurement of variables was not considered. The appropriate sequence is to formulate a conceptual framework. Then, given this body of concepts, the next task is to select measuring instruments. This sequence was followed in the study.

Every effort was made to identify and utilize existing measuring instruments where applicable to the particular measurement task at hand. In situations where this was not possible, specific instruments were developed for use in the study.

The variable system outlined in Figure 5 in Chapter 3 provides a helpful identification of the variables discussed on the following pages. The sequence of discussion of variable measurements ranges from the independent set, including the individual, task, and joint domains, to the dependent information-processing set. Each variable is discussed in terms of the particular measuring instrument to be utilized, source of measurement, unit of measurement, level of measurement, and time and frequency of measurement.

Individual Domain

The three groups of variables pertaining to the individual are: (1) Idiosyncratic, (2) Intellective, and (3) Cognitive. Each of the variables in these groups was measured independent of a particular task.

Idiosyncratic variables. The two measures in this group were Experience (P_1) and Job Performance (P_2).

Experience (P_1) was measured in two ways. An aggregate measure was obtained in terms of the years of professional experience of the subject. A second measure, ARAC job experience, was utilized to attempt to allow for possible job learning curve influences. The aggregate measure included ARAC experience. Work accomplished as a part of university-industry cooperative programs was counted as well as applicable summer professional experience. Work in ARAC was counted on the basis of 60 percent of full time in view of the 24 hour work week. Data was obtained from personnel records and supplemented where necessary by personal interviews. The level of measurement was on an interval scale. Measurement was as of February 1, 1967.

The measurement of Job Performance (P_2) was approached along two avenues. A ranking instrument was utilized to obtain independent job performance rankings of subjects from three ARAC managers. Each worked closely with the subjects on a day-to-day basis. The instrument is shown in Appendix A.

A second instrument was developed using the same criteria as were used in the ranking instrument above. This measurement resulted in a rating index for each subject ranging from very low performance (1.0) to extremely high performance (7.0). The Job Performance Rating form is shown in Appendix B. Ratings on each subject were obtained from the same three ARAC managers as for the subject rankings.

The criteria used as a base reference for the ranking and rating instruments were a set of relevant job performance factors. These were developed through personal interviews with ARAC management personnel. The criteria utilized were the results of the combined judgments of the management group.

Intellective variables. Two measures were utilized in attempting to identify intellective variation among subjects. Test results on the Admission Test for Graduate Study in Business were already on record in the Indiana University Graduate School of Business for 16 of the subjects.[8] These results were available in two parts (verbal and quantitative) as well as an aggregate score.

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[8]Administered by the Educational Testing Service, 20 Nassau Street, Princeton, New Jersey.

The Wonderlic Personnel Test was utilized as a second intellective measure.[9] This instrument was developed by E. F. Wonderlic to aid in examining and measuring mental abilities of adults in business and industrial situations. The test has been standardized in a business situation on adults with age ranges from 20 to 65 and with various work backgrounds.[10]

Cognitive variables. Two existing instruments were utilized to measure the cognitive dimensions, Risk-Taking Propensity (P_4) and Information-Processing Efficiency (P_5). The instrument used to measure risk-taking propensity was the Kogan and Wallach "Choice Dilemmas Procedure."[11] This is a twelve item instrument in which each item represents a choice dilemma between a risky and a safe course of action. The subject is asked to select the probability level for the risky alternative's success that will make it sufficiently attractive to be chosen. The procedure is of a semi-projective nature in that the subject is asked how he would advise others for each of the twelve situations. As an example of the instrument, situation Number 5 from the Choice Dilemmas Procedure is shown in Appendix C.

Use of the Choice Dilemmas Procedure involved the assumption that the subject's advice to others reflected his own regard for the desirability of success relative to the dis-utility of failure. The validity of this

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[9]E. F. Wonderlic, Wonderlic Personnel Test Manual (Northfield, Ill.: E. F. Wonderlic and Associates, Inc., 1966).

[10]Ibid., p. 3.

[11]Nathan Kogan and Michael A. Wallach, Risk Taking: A Study in Cognition and Personality (New York: Holt, Rinehart and Winston, 1964), pp. 256-261.

assumption may be questionable since there are certain ambiguities present on at least eight of the twelve questions according to Professors Cummings and Harnett of the Indiana University Graduate School of Business. They have modified the instructions on the Kogan and Wallach instrument in an attempt to overcome these ambiguities.

The original version of the instrument was utilized in this study because of the extensive base of results available for comparative purposes. The possible scores on the test range from 12 to 120, with a larger score reflecting greater conservatism.

It is important to note that Kogan and Wallach have used the instrument to measure risk-taking propensity as a dependent variable. In the present study risk-taking propensity was considered as an independent variable. Professors Harnett and Cummings have utilized the instrument in a similar way.

A modified approach to that utilized by Hayes was followed to obtain an information-processing efficiency index for each subject.[12] Each subject was provided with 32 decision situations each containing eight alternatives and eight characteristics describing each of the alternatives. Decision quality and decision time were measured. A weighted decision time/quality index was calculated to serve as a measure of each subject's information-processing efficiency. Complete details concerning the measurement of the index are shown in Appendix D. Hayes' research was discussed in Chapter 2.

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[12]John R. Hayes, Human Data Processing Limits in Decision Making, Report No. ESD-TDR-62-48 (Bedford, Mass.: Air Force Systems Command, Electronic Systems Division, July, 1962).

Task Domain

The two groups of variables pertaining to the task are: (1) Situational and (2) Evaluational.

An instrument called a Task Record was developed for use in recording task variable measurements. This is shown in Appendix E, along with instructions for completing the form. Each of the variables in these groups was measured independent of a particular individual. Measurements of each task variable were obtained from the ARAC Retrospective Search Service supervisor. Task variable measurements could have been obtained from each subject for a given task. However, by obtaining all task measurements from one individual a greater degree of consistency of measurement among tasks appeared probable.

Situational variables. The variables included in this group were Field (T_1), Major Output (T_2), Task Function (T_3), and Time Span (T_4). In terms of the homogeneity of the tasks included in the study it was not anticipated that variables T_1, T_2, and T_3 would vary to the degree that their possible influence upon information-processing could be investigated. Additionally, the task sample was too small to obtain sufficient observation of this variable in the categories available. However, a measurement of each was obtained according to a classificatory scale. Investigation of possible relationships based on these dimensions of variation was not attempted.

Classification of Field (T_1) was accomplished using the categories established by ARAC for identifying the field of each task. These are shown in Appendix F. Measurement was accomplished upon receipt of each task.

Major Output (T_2) was measured using the categories provided in the Auerbach study.[13] The major output referred to whether the output was a finding, a recommendation, a decision, or other. The categories used are shown in Appendix E.

The Task Function (T_3) referred to the kind or level of output with respect to the use of the task result. A modified version of the categories provided in the Auerbach study was utilized.[14] This is shown in Appendix E.

The Time Span (T_4) of each task was measured in terms of the elapsed time (in working days) from receipt of a task to its completion.

Evaluation variables. The variables included in this group were the Precision of Definition (T_5), Scope and Complexity (T_6), and Results (T_7) of the task.

A rating scale was utilized to assign to each task an index of precision of definition, ranging from poorly defined (1) to well defined (7). Precision of definition was measured in terms of the information provided (task objectives and constraints) on the task when it was received. The rating was accomplished upon receipt of each task.

Two measures were included to characterize the scope and complexity of each task. The first was a rating obtained by asking the RSS supervisor to rate each task from 1 to 7 based on the difficulty anticipated in gaining a solution. The second measure utilized the technical man-hours invested on each task to reflect task scope and complexity. Using

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[13]Auerbach Corporation, DOD User Needs Study, Phase I-Vol. I (AD-615501), May 14, 1965 (Philadelphia: Auerbach Corporation, 1965), p. B-13.

[14]Ibid., p. B-11.

this basis of measurement it was assumed that the scope and complexity of a given task were reflected in the amount of technical effort required to complete the task.

The two-dimensional measurement of scope of complexity was included to guard against task situations where a single measure might not adequately represent scope and complexity. The rating was accomplished at the outset of the task. The man-hours invested were obtained from accounting records at the completion of each task.

Measurement of results was intended to get at how well the problem was solved in terms of specified objectives and constraints. A rating scale of 1 through 7 was utilized to obtain a result rating for each task. The rating was accomplished at the completion of each task by the RSS supervisor.

Interaction Domain

The four variables pertaining to the interaction of individual and task were: (1) Image State for Task (J_1), Interest in Task (J_2), Certainty of Outcome (J_3), and Ordinal Position of Task (J_4). Measurements of these variables were obtained from each subject. The data were obtained with respect to each task assigned to a particular subject. The instrument developed for use in obtaining measures on these four variables was the Search Record which is shown in Appendix G.

A Search Record was given to each subject upon receipt of each task included in the study. It was completed in the presence of the researcher. An additional Search Record was also completed at the conclusion of each task.

The entropy concept of information theory formulated by Shannon was utilized to gain a measure, or index, of each subject's image state for a particular task.[15] The concept of a human being as a communication system in the context of information theory was developed and discussed in Chapter 2.

On a given task the subject was asked to do three things to provide the required information for the computation of his image state index for a particular task. First, he was asked to list the alternative sources of information which he believed might contain information relevant to the task. In view of the information seeking nature of the tasks included in the study, these sources were viewed as equivalent to various decision alternatives for the task. The various sources of information for the tasks included in the study were in effect "solution paths."

The subject was next asked to indicate the probability that a particular information source contained relevant information. The subject was told that each probability estimate was independent and that the estimate did not refer to the quality of information contained in the source. This probability estimate was identified as q_i.

The third aspect of the image state measurement was to ask the subject to specify for each alternative source of information the conditional probability that if the source contained relevant information, then how good (quality) was it expected to be. This probability estimate was identified as r_i.

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[15]Claude E. Shannon and Warren Weaver, The Mathematical Theory of Communication (Urbana, Ill.: The University of Illinois Press, 1964).

These three measurements were combined into the following measure of a subject's image state for a task:

$$\text{Image State } (J_1) = -\sum_i P_i \log_e P_i$$

Where i is the number of alternative sources listed and $P_i = q_i r_i$.

It was assumed that an individual's image state at the outset of a task would be a more sensitive influence on his information-processing activity than an average of J_1 over the time span of the task. The change of J_1 during the task provided the measure for the information-processing variable (I_{10}). This is discussed later in the chapter.

The measurement of a subject's interest in a task (J_2) was based on the approach utilized by Morris.[16] He used a rating scale ranging from 1 through 7, with 1 reflecting low interest and 7 relatively high interest. A rating was obtained at the outset of each task and at its conclusion. These measures were combined to obtain an average measure of J_2 over the time span of the task. It was assumed that the subject's interest in a task would vary during the task such that an average measure would be most appropriate.

The uncertainty of the subject toward the outcome of a task (J_3) was obtained by asking each subject to make a subjective probability estimate concerning the outcome of the task. Measurement was accomplished before work was initiated on a task. The base of reference for assessing uncertainty of outcome was provided by the objectives and constraints specified for the task at its outset.

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[16] Charles G. Morris, Effects of Task Characteristics on Group Process, Technical Report No. 2, AFOSR-65-1519 (Urbana, Ill.: University of Illinois, Department of Psychology, July, 1965), p. 100.

The ordinal position of a task (J_4) with respect to all others being handled by a particular subject was obtained by a simple ranking. The subject was asked to indicate how many tasks he was currently working on. If, for example, he had 3 in process then the ordinal position for the task at hand was 4. The measurement was obtained only at the outset of the task recognizing that J_4 could change over the time span of the task. It was assumed that the initial measure would be the most sensitive relative to the information-processing activity of the subject.

Information-Processing Domain

The four groups of variables pertaining to information-processing are those included in the Search, Receipt, Evaluation, and Integration phases. These were the dependent variables of the study. All measurements were obtained from the subjects of the study with respect to each assigned task. Data were recorded on two instruments developed for use in the study. These were the Diary of Information Sources and Diary of Information Elements. They are shown in Appendix H and Appendix I, respectively. Each variable is identified on the forms by the symbol I_i.

The Diary of Information Sources and Diary of Information Elements were maintained by each subject for the duration of each task. Regular contact was made by the investigator with each subject to answer any questions that developed, as well as to assure the dynamic recording (at the time of occurrence) of data during the time span of the task. The use of the two structured diaries represented an attempt to obtain a "play-by-play" recording of the subject's information-processing activities. It was felt that an effort by the researcher to record this information as it happened by sitting alongside the subject would adversely influence the information-processing behavior of the subject.

It is important to note that use of the two diaries also involved a possible problem with respect to whether the investigator was actually measuring what he thought he was measuring. Banks has identified two sources of internal validity which are related to this problem.[17] These are testing and instrument decay. The first concerned the possible structuring influence of the diary which might affect the problem solving behavior of the subject. The second involved the consistency of the subject in recording data in the diary over the time span of a task.

It seemed likely that the major influence of the diaries would be to increase the time for completion of a task rather than to change a subject's problem solving behavior. Additionally, consistency of response was not anticipated to vary to any meaningful degree. Observation of the subjects during the study and review of the data collected appeared to substantiate these assessments.

Search phase. The variables included in this group were Sources Sought (I_1) and Search Investment (I_2).

Three measures of sources sought were obtained. These were the total number of sources sought, the number of external sources, and the number of internal sources. A simple counting of sources in these categories from the Diary of Information Sources (Appendix H) provided the measure.

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[17] Seymour Banks, "Designing Marketing Research to Increase Validity," Journal of Marketing, XXVIII (October, 1964), pp. 33-34.

Two measures of search investment were obtained. These were the total search time (in hours) and the average search time (in hours) per source. Total search time consisted of the sum of Column D of the Diary of Information Sources. The average search time per source was obtained by dividing total search time by the total number of sources sought.

Receipt phase. As indicated in Chapter 3 the variables contained in this phase were included to aid in identifying information elements during the remainder of the task process. Channel/Media (I_3), Element Type (I_4), and Timing/Order of Arrival (I_5) were recorded in Columns D, E, and A, respectively, of the Diary of Information Elements (Appendix I). Variables I_3 and I_4 were assigned to the categories indicated in the instructions in Appendix I.

Evaluation phase. Beginning with this phase throughout the remainder of the decision process the information element was the basic unit of analysis. Measurements were made on all elements received by the decision maker, regardless of whether or not they were ultimately rejected as being applicable to the task. The variables measured in this group included Competency and Reliability (I_6) of the element's source, Relevance to Task (I_7), Image State Conflict (I_8), and Evaluation Investment (I_9).

For control purposes the total number of information elements received on a given task was recorded as well as the breakdown between accepted and rejected elements. This information was obtained from the Diary of Information Elements.

A rating scale ranging from 1 through 7 was used to obtain a measure of the competency and reliability of the information source of each element. The subject was asked to indicate a rating for each element received. In order to obtain an over-all measure of I_6 for a given subject/task situation, the mean rating for all elements was used. This provided the advantage of an aggregate measure for convenience of analysis and at the same time allowed a build-up of the aggregate measure via individual information elements. The aggregate measure of I_6 included a mean for all elements as well as means for both the accepted and rejected element groups.

Similar scales were used to measure task relevance and the element's image state conflict. For each of these variables a mean rating for the total number of task elements was obtained along with means for the accepted and rejected element groups.

It is important to note that a subject's ratings for variables I_6, I_7, and I_8 were made at the time the particular element was evaluated. Recognizing the dynamic nature of the problem solving process it was quite possible that the subject's ratings for a given element would not have been the same if the evaluation had occured earlier or later in the time span of the task. Also, it must be emphasized that these measures were subjective in that two subjects might rate differently the same element for the same task. These measurements were directed toward describing information-processing with respect to the individual, rather than to attempt to determine how well (in a normative sense) information-processing was being accomplished.

Evaluation Investment (I_9) was measured in terms of the total time for evaluation of all elements, and each of the mean times, per element, for the accepted and rejected element groups.

Upon completion of evaluation of each element, the subject was asked to indicate an accept/reject decision. At this point the element was at the integration stage. Information-processing was complete on an element at the completion of evaluation if it was rejected by the subject.

Integration phase. Three variables were measured during the integration of each accepted element into the task. These were Image State Change (I_{10}), Contribution to Result (I_{11}), and Integration Investment (I_{12}). The subject was also asked to record whether or not each element was prescriptive (a mandatory effect on the task with respect to objectives and/or constraints). Measurements for I_{11} and I_{12} were recorded in Columns L and M, respectively, on the form shown in Appendix I.

Image State Change (I_{10}) was obtained by subtracting zero from the image state index (J_1) at the outset of a task. On this basis:

Image State Change (I_{10}) = $(J_{1_o} - J_{1_t})$, where $J_{1_t} = 0$

It was assumed that at the completion of a task a subject's image state for that task was equal to zero. In other words, his information at this point was perfect. The information searched for, evaluated, and integrated aided the subject in moving from his initial image state to a perfect state of zero.

A rating scale of 1 through 7 was used to measure the contribution of each element to the task result. This rating was accomplished at the completion of integration of each element. A mean rating of accepted elements served as a measure of I_{11}.

Integration investment (I_{12}) was obtained in terms of the total technical man-hours expended on element integration and the average time per information element. In some cases it was possible that no further time was invested in an element beyond the "accept" decision. In these cases the two dimensions of I_{12} had values of zero.

METHOD OF ANALYSIS

The relationships of interest in the study were identified in the latter part of Chapter 3. These involve an assessment of the total impact of the independent variables on the set of dependent variables as well as the impact on certain subsets of the dependent group. A multivariate statistical technique is appropriate for this task.

Canonical correlation analysis is a statistical technique well suited to investigating the relationships of interest in the study. Canonical analysis is a more general statistical model of which multiple correlation is a special case. The canonical model seeks to relate two sets of variables in as many independent ways as possible.[18] As Veldman points out:

> "The goal of canonical analysis is to define the primary independent dimensions which relate one set of variables to another set of variables. The technique is primarily descriptive, although the method used involves finding sets of weights which will yield two composite variables (one for each set of original variables) which will correlate maximally."[19]

Canonical analysis provides three main outputs:[20]

1. The <u>number</u> of ways in which two sets of variables are related.

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[18]Donald J. Veldman, "Chapter II, Regression Analysis," <u>FORTRAN Programming for the Behavioral Sciences</u> (New York: Holt, Rinehart and Winston, 1967), p. 2.

[19]<u>Ibid</u>., p. 3.

[20]<u>Ibid</u>., p. 3.

2. The indicated <u>strengths</u> of these relationships.

3. The <u>nature</u> of the relationships which are defined.

Canonical analysis begins with a correlation matrix (validity matrix) between all possible sets of two variables.[21] The matrix of intercorrelation, R, is partitioned as indicated below:

$$\bar{R} = \left[\begin{array}{c:c} \bar{R}_{ii} & \bar{R}_{ij} \\ \hdashline \bar{R}_{ji} & \bar{R}_{jj} \end{array}\right]$$

Where

$\bar{R}_{ii}$ = intercorrelations among the dependent variables,

$\bar{R}_{jj}$ = intercorrelations among the independent variables,

$\bar{R}_{ij}$ = intercorrelations of dependent with independent variables,

$\bar{R}_{ji}$ = transpose of $\bar{R}_{ij}$.

Next, a product matrix is formed to reflect the relationship pattern between the two sets of original variables.[22] The canonical equation is written in two ways:[23]

$$(\bar{R}_{ii}^{-1}\ \bar{R}_{ij}\ \bar{R}_{jj}^{-1}\ \bar{R}_{ji} - \lambda I)a = 0 \qquad (1)$$

and

$$(\bar{R}_{jj}^{-1}\ \bar{R}_{ji}\ \bar{R}_{ii}^{-1}\ \bar{R}_{ij} - \lambda I)b = 0 \qquad (2)$$

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[21]The following mathematical discussion is drawn from the Technical Appendix of Paul E. Green, Michael H. Halbert, and Patrick J. Robinson, "Canonical Analysis: An Exposition and Illustrative Application," <u>Journal of Marketing Research</u>, III (February, 1966), pp. 32-39.

[22]Veldman, <u>op. cit.</u>, p. 5.

[23]Green, Halbert, and Robinson, <u>op. cit.</u>, p. 38.

Equation (2) can be solved by seeking the appropriate characteristic roots of λ_K which result in:

$$\left| \bar{R}_{jj}^{-1} \bar{R}_{ji} \bar{R}_{ii}^{-1} \bar{R}_{ij} - \lambda I \right| = 0 \qquad (3)$$

Then a substitution can be made to obtain the vector b related to the value of λ. The vector a is obtained from:

$$a = \frac{\bar{R}_{ii}^{-1} \bar{R}_{ij}\, b}{(\lambda)^{\frac{1}{2}}} \qquad (4)$$

The square root of each value of λ is equal to a canonical correlation coefficient. The maximum number of independent values which can be obtained is equal to the number of variables in the smaller of the two variable sets. For example, if the smaller set contains two variables, there will be solutions λ_1 and λ_2. Veldman in commenting on this indicates that:

> "The term 'independent' ..... implies that the composite scores for successive canonical variables will be uncorrelated on each side, and when cross-correlated will yield a diagonal matrix of canonical correlation coefficients."[24]

The vectors a and b represent the weights for each of the variables in the dependent and independent sets. For each value of λ there will be different values for vectors a and b.

As with any statistical model canonical analysis rests upon certain assumptions. The two main assumptions of canonical analysis (for testing of statistical significance) are:[25]

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[24]Veldman, op. cit., p. 5.

[25]Green, Halbert, and Robinson, op. cit., p. 36.

1. Both sets of variables (dependent and independent) are measured at a level stronger than classificatory.

2. Data observed is a random sample of observation vectors drawn from the same multinormal universe.

While the multinormality assumption can be limiting, there are indications that the test of statistical significance used in canonical analysis is rather robust for samples of moderate size. In commenting on this Green _et al_. indicate that:

> "The assumption of multinormality (and, hence, linearity) can also be restrictive if statistical significance is to be ascertained. As in traditional multiple correlation, the analyst may be able to make suitable transformations in order to achieve linearity, but in dealing with small samples, the linearity assumption must usually be made by necessity; experimental error is typically large enough to mask the possibility that non-linearity is present. As the number of variates increases, however, the multivariate extension of the central limit theorem indicates that moderate departures from multinormality probably do not lead to serious errors in the application of significance tests which are based on multinormal distributions."[26]

Testing the significance of the roots of λ can be accomplished using a distribution which is approximately Chi-squared (X^2). The theory underlying the test is discussed by Bartlett.[27]

The calculations associated with canonical analysis are extremely involved and time-consuming. Fortunately, there are computer programs available for this task. The program utilized in this study was developed by Professor Donald J. Veldman at the University of Texas and is called the CANONA program. It is described in Chapter 11 of his forthcoming book, _FORTRAN Programming for the Behavioral Sciences_.[28] At least two

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[26] _Ibid_., p. 36.

[27] M. S. Bartlett, "The Statistical Significance of Canonical Correlation," _Biometrica_ XXXII (1941).

[28] Veldman, _op. cit_., pp. 32-39.

other "canned" programs are available.[29] Execution time (after compiling) for the CANONA program is about two minutes for a 13 by 13 variable group on a Control Data Corporation 3600 system.

The interpretation of the outputs of canonical analysis needs to be made explicit. First of all, the "number of multivariate relationships between the two sets of variables is suggested by the number of significant canonical correlations obtained."[30] The degree to which these relationships are explained by the correlations is provided by the ratio of the square of the canonical roots to one (1.0).

Getting at the nature of the canonical relationships is not quite as straightforward. Veldman points this out in the following:

> "Although the vectors of weights ..... do indicate the relative contribution of each of the original variables to the computation of the composite canonical scores, interpretation of these weights as indicators of the nature of the canonical relationships concerned may be quite misleading. What we need for this purpose are correlations between the original variables and the canonical variables on each side. In the multiple regression model these correlations are the validities since the B-side[31] weight is 1.0. In the canonical correlation model, however, the validity matrix R_{AB} reflects only the relationships between pairings of the original variables."[32]

The CANONA program provides these correlations which as Veldman points out for "large coefficients for a particular canonical function

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[29]See William W. Cooley and Paul R. Lohnes, Multivariate Procedures for the Behavioral Sciences (New York: John Wiley & Sons, Inc., 1962), pp. 31-59, and the "Biomedical Package" of University of California at Los Angeles available through many university computing centers.

[30]Veldman, op. cit., p. 10.

[31]The A and B sides refer to the two sets of variables.

[32]Ibid., p. 8.

can be interpreted like factor loadings, in terms of the names of the original variables, as suggesting the content of the composite dimension."[33]

[33] *Ibid.*, p. 10.

CHAPTER 5

ANALYSIS OF RESULTS

In this chapter the analysis of the empirical data collected in the study is presented and discussed. In the first section the results of the canonical analysis of the data are summarized. The next section examines in detail the role of the independent variables in the system of variables. In the third section certain subgroups of independent variables are considered as possible correlates of information-processing. In the final section is a note on the predictive application of the system of variables.

SUMMARY OF RESULTS

The set of independent variables drawn from the individual, task, and individual/task interaction domains was found to be highly correlated with the dependent set of information-processing variables. The canonical correlation coefficient between the independent and dependent sets was 0.940 and was significant at an alpha level of 0.001. By analogy to simple correlation this refers to the correlation between the two sets or clusters of variables. In other words, the correlation indicates that if all of the variables in the system are considered as two sets, one independent and one dependent, then the correlation between the two sets is provided by the canonical correlation coefficient.

The relatively high canonical correlation between the independent and dependent variable sets suggests that there is a significant linkage between the two sets. This is not an unexpected finding since certain of the variables selected as potential correlates of information-processing have been found in previous research to impinge upon the decision-making domain in general and the information-processing domain in particular (although to a lesser degree). Applicable research foundations were discussed in Chapter 2. Additionally, canonical correlation typically would be expected to indicate an association in excess of that of any single pair of variables drawn from two sets of variables.

The canonical correlation coefficient (or index) can be interpreted as a measure of the over-all association between two sets of variables. It is interesting to compare this index (0.940) with the simple correlations between pairs of independent and dependent variables as shown in Appendix K. The canonical correlation is higher than any of the coefficients between all pairs of the thirteen independent and dependent measures included in the analysis. The highest simple correlation (0.504) is between the task result rating and external sources sought. Thus, the combined effect of the two sets of variables indicates a greater association than any of the combinations of pairs.

The roles or contributions of the individual variables in each set were not the same. Certain variables played a stronger role than did others. Information-Processing Efficiency, Image State, Task Result, and Risk-Taking Propensity were found to be the key contributors in the independent set. In contrast to this, Task Scope and Complexity, Task Time Span, Uncertainty of Outcome, Experience, and Ordinal Position of Task were found to play almost negligible roles in the independent set.

Job Performance, Interest in Task, Intellective Aptitude, and Precision of Definition of Task were found to make relatively modest contributions to the independent set.

The major contributions to the dependent set were provided by the variables; Sources Sought, Competency/Reliability, Evaluation Investment, and Relevance to Task. Negligible roles were found in regard to the variables; Rejected Elements Processed and Search Investment. Modest contributions to the dependent set were found for Accepted Elements Processed, Image State Conflict, and Integration Investment.

It is important to note that a high direct correlation is not indicated, for example, between an independent and dependent variable as a result of each variable's major contribution to its particular set. The most that can be said via canonical analysis is that variable x_i makes a major contribution to the independent set which in turn is highly correlated with the dependent set, and variable y_i plays a major role in the dependent set. This indirect linkage is the extent of the association which can be observed via the canonical analysis of the data.

While this was an exploratory study which sought to gain a better description of individual information-processing, it seems appropriate to speculate concerning the four independent variables which contributed so highly to the apparent association with the dependent variable set.

First of all it is interesting to note that each of these four variables (information-processing efficiency, image state, task result, and risk-taking propensity) represents one of the three independent domains of the individual, the task, and the individual/task interaction. This suggests that all three domains are relevant correlates of individual information-processing. Of additional interest is the fact that information-processing efficiency and risk-taking propensity were measured before the outset of any tasks included in the study; image state was measured at the outset of each task; and task result at the completion of each task. The measures were obtained at different stages in the decision process.

The next consideration is that of speculating on why these variables rather than others in the independent set stand out as potential correlates of individual information-processing. The rationale for selecting these variables provides a partial explanation.

The efficiency with which an individual processes information seems to be a logical individual characteristic which might be expected to be related to such dependent characteristics as sources sought, competency and reliability of information elements processed, and information element evaluation investment. While it would be hazardous, in the abstract, to pinpoint information-processing efficiency as the <u>major</u> characteristic impinging upon individual information-processing, certainly its inclusion in a conceptual model of individual information-processing seems logical.

In a similar context an individual's image state for a task suggests a likely correlate of information-processing. For example, an individual with a limited image state for a task would seem to be more inclined to seek information from more sources than if his image state were relatively extensive, all other things being equal. The results of the study tend to substantiate this.

It would also seem logical that a task result and individual information-processing should be associated. Information-processing should be expected to vary relative to the task result achieved if, in fact, information-processing is an important part of decision-making. This linkage was considered in Chapter 2. The results of the study indicate a definite impingement of task result on information-processing characteristics.

Finally, the influence of an individual's risk-taking propensity on his information-processing behavior seems reasonable since prior research has suggested such an association with respect to decision-making, and information-processing appears to be a part of decision-making.

Thus, the association of these particular independent variables and those in the dependent group seems meaningful. Their inclusion in the conceptual variable system was guided by previous research combined with the insights of the investigator. The major objective of the analysis was to determine the relative contribution of each of the independent variables to the total system.

ROLES OF INDEPENDENT VARIABLES

Nature of Canonical Relationships

Thirteen measures were included in the canonical analysis of data for each of the dependent and independent variable groups. These are shown in Table I. The variable system used in the study presented a possible problem in that a tautology or redundancy might possibly exist among certain of the variable measures used. Care was taken to avoid this problem by eliminating certain measures in the canonical analysis of the data. This is discussed in Appendix M.

TABLE I

Variables and Measures Used in Investigating Relationships

VARIABLES	MEASURES USED
INDEPENDENT SET	
INDIVIDUAL	
Experience (P_1)	ARAC Experience
Job Performance (P_2)	Performance Index
Intellective Aptitude (P_3)	Wonderlic Score
Risk-Taking Propensity (P_4)	RTP Index
Information-Processing Efficiency (P_5)	IPE Index
TASK	
Time Span (T_4)	Days
Precision of Definition (T_5)	Rating
Scope and Complexity (T_6)	Rating
Result (T_7)	Rating
INDIVIDUAL/TASK	
Image State for Task (J_1)	Image State Index
Interest in Task (J_2)	Interest Rating
Uncertainty of Outcome (J_3)	Probability Estimate
Ordinal Position of Task (J_4)	Rank of Task
DEPENDENT SET	
SEARCH PHASE	
Sources Sought (I_1)	Internal Sources
	External Sources
Search Investment (I_2)	Average Hours/Source

TABLE I (Continued)

EVALUATION PHASE	
Elements Processed	Number Rejected
	Number Accepted
Competency/Reliability (I_6)	Mean Rating (Rejected Elements)
	Mean Rating (Accepted Elements)
Relevance to Task (I_7)	Mean Rating (Rejected Elements)
	Mean Rating (Accepted Elements)
Image State Conflict (I_8)	Mean Rating (Rejected Elements)
	Mean Rating (Accepted Elements)
Evaluation Investment (I_9)	Total Evaluation Hours
INTEGRATION PHASE	
Integration Investment (I_{12})	Total Integration Hours

In canonical correlation variables are analyzed in groups or sets such that the canonical correlation coefficient reflects the association between two sets of variables. This correlation between sets is analogous to simple correlation where the correlation coefficient, r_{xy}, indicates the association between variables x and y.

The individual variables in each set contribute as a group to the canonical correlation between sets. However, the individual roles of the original variables in the canonical correlation are also of interest. Some variables make more important contributions than others.

A helpful way to think of the variables in each set is to represent them by two composite or proxy variables, x^* and y^*.[1] The correlation between these two composite variables is the canonical correlation coefficient, $r_{x^*y^*}$. An indication of the importance of the role of each variable in the canonical system is reflected by the correlation between each original variable in a given set and the composite variable for that set. Veldman indicates that the correlations between the original variables and the canonical variables can be viewed as factor loadings in that large correlation coefficients for particular variables indicate that these variables contribute more to the set than do those with smaller coefficients.[2] Thus, a high correlation between a particular variable and

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[1]A composite canonical variable is, in effect, a proxy variable for a group of single observations of each variable in a variable set. For example, using the basic data for the independent variable measures associated with Task 26 (see Appendix J-3), the canonical score for this set of observations would be equal to: $a_1 x_1 + a_2 x_2 + \cdots + a_{13} x_{13}$. The a_i are the weights assigned to each variable measure via canonical analysis and the x_i are the standardized values (mean equal to zero and standard deviation equal to one) for the thirteen measures.

[2]Donald J. Veldman, "Chapter II, Regression Analysis," FORTRAN Programming for the Behavioral Sciences (New York: Holt, Rinehart and Winston, 1967), p. 10.

the canonical composite variable suggests an important role for that variable in the canonical system.

Thus, via a sequence of steps, the structure of the entire system of variables can be established. Figure 8 provides a helpful frame of reference for tracing the linkage of the original independent and dependent variables and the composite variables.

In terms of Figure 8, the correlation coefficients, $r_{x_i x^*}$ and $r_{y_i y^*}$ indicate the importance of each variable in the system. These are the correlations between the original variables and their composite or proxy variable. The correlation coefficient $r_{x_i x^*}$ links the original variable to the composite variable. The $r_{x^* y^*}$ is the canonical correlation coefficient between the two sets. The variables in the dependent set are linked to their corresponding canonical variable, y^*, by $r_{y_i y^*}$. These correlations provide a basis for discussing the direction and magnitude of influence of each independent variable measure. The composite correlations ($r_{x_i x^*}$ and $r_{y_i y^*}$) for the independent and dependent variable sets are shown in Tables II and III, respectively.[3]

Interpretation of Individual Roles

The nature of the association of variables in the system can be described as follows: The information-processing efficiency (IPE) index

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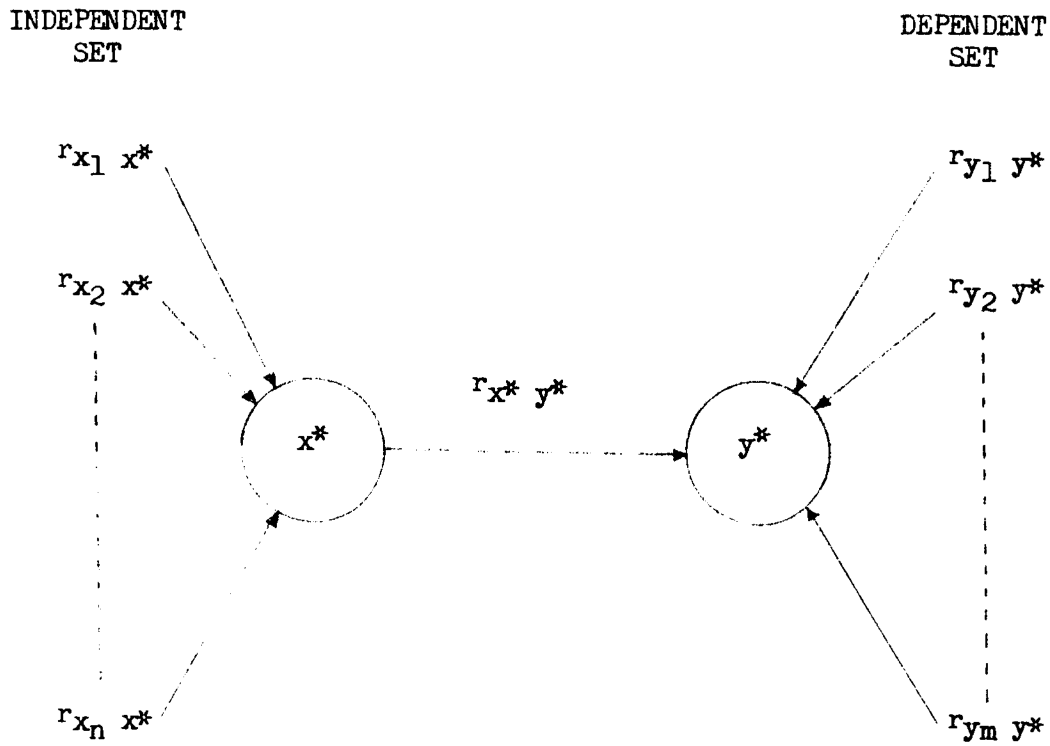
[3] The composite correlations in Tables I and II pertain to the first canonical root extracted (0.940^2). A total of 13 independent roots were extracted and four were statistically significant at alpha levels of less than 0.05. However, the first canonical root is of primary interest since it is the strongest (highest canonical correlation coefficient, $r_{x^* y^*}$) of the 13 roots extracted. The complete group of roots is shown in Appendix L along with the probabilities at which the hypothesis that a relationship exists would be rejected.



$x_1, x_2, \cdots\cdots, x_n$	=	Independent variables
$y_1, y_2, \cdots\cdots, y_m$	=	Dependent variables
x^*	=	Composite variable, independent set
y^*	=	Composite variable, dependent set
$r_{x_i} x^*$ or $r_{y_i} y^*$	=	Correlation coefficient between an original variable and the composite (or proxy) variable
$r_{x^*} y^*$	=	Canonical correlation coefficient between the two variable sets.

Figure 8 — Linkage of Original and Composite Variables

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TABLE II

Composite Correlations for Independent Measures in Decreasing Order of Magnitude

Variable Measure	Correlation: Variable and Composite ($r_{x_i x^*}$)
Information-Processing Efficiency Index	0.7005
Image State Index	0.3966
Task Result Rating	0.3638
Risk-Taking Propensity Index	-0.2732
Job Performance Index	0.1642
Interest in Task Rating	-0.1500
Intellective Aptitude (Wonderlic Score)	0.1162
Precision of Definition Rating	-0.1002
Scope and Complexity Rating	-0.0960
Time Span (Days)	0.0750
Uncertainty of Outcome (Probability Estimate)	0.0438
ARAC Experience	-0.0384
Ordinal Position of Task	-0.0090

TABLE III

Composite Correlations for Dependent Measures
in Decreasing Order of Magnitude

Variable Measure	Correlation: Variable and Composite ($r_{y_i y^*}$)
Sources Sought (Internal)	0.6342
Competency/Reliability (Rejected Elements)	0.4249
Evaluation Investment (Hours)	0.3352
Relevant to Task (Accepted Elements)	-0.3336
Accepted Elements Processed	-0.2793
Relevance to Task (Rejected Elements)	0.2734
Image State Conflict (Accepted Elements)	0.2110
Integration Investment (Hours)	0.2109
Sources Sought (External)	0.1482
Image State Conflict (Rejected Elements)	0.0983
Rejected Elements Processed	0.0720
Competency/Reliability (Accepted Elements)	-0.0568
Search Investment (Hours/Source)	0.0352

has the highest correlation (0.701) with the composite variable of any of the measures in the independent set. A high value of the index reflects a relatively low information-processing efficiency.[4] Thus, individuals with relatively low information-processing efficiency (as measured by the IPE index) appear to be positively associated with the independent canonical composite which in turn is positively related to the dependent canonical composite.

An individual's image state index for a particular task refers to his combined state of knowledge concerning the task at its outset. It has the second highest correlation (0.397) with the independent composite variable. The correlation is positive. Note, however, that the lower the value of the index, the higher is the individual's state of knowledge. An index of zero reflects a state of perfect information.

Task result rating has the third highest correlation (0.364) with the canonical composite. High values of the task result rating are positively associated with high values of the canonical composite.

The risk-taking propensity index has the fourth highest correlation (-0.273) with the canonical composite variable. A relatively high value of the index is intended to identify a risk-evader. Thus, individuals with risk-taking tendencies (as measured by the RTP index) are associated with high values of the independent canonical composite.

The strength of the association of each of the remaining nine independent measures is reflected by the composite correlation coefficient shown in Table II.

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[4]Recall that IPE was measured in terms of decision time divided by decision quality (see Appendix D). Thus, according to the measure the higher the IPE index the lower the information-processing efficiency.

The nature of the association of the original dependent variables with their composite provides the remaining part of the interpretation of individual variable roles. Referring to Table III, a relatively high number of internal information sources sought, high competency/reliability rating for rejected elements processed, high evaluation investment, low relevance to task for accepted elements, and low numbers of accepted elements are positively associated with the dependent canonical composite. Thus, a linkage is provided between variable measures in the independent set and measures in the dependent set. The additional dependent measures are related to the total system in the magnitudes and directions indicated in Table III.

Information-Processing Phases

Conceptually, the dependent set of variables was broken down into three phases: search, evaluation, and integration. These variables are listed according to phase in Table IV along with the correlation of each with the dependent composite variable.

The composite correlations in Table IV provide a guide to the importance of each phase. The search phase contains the variable (sources sought) with the highest composite correlation in the set. The evaluation phase has five measures with composite correlations in excess of 0.250. The single variable in the integration phase (integration investment) has a composite correlation coefficient equal to 0.2109.

The search phase seems clear cut both from conceptual and data collection standpoints. The subjects of the study did, however, experience some difficulty in drawing a clear cut line between search and evaluation investment. The identification of the evaluation and integration phases

TABLE IV

Composite Correlations for Dependent Measures Grouped by Information-Processing Phase

Variable Measure	Correlation: Variable and Composite
SEARCH PHASE	
Sources Sought (Internal)	0.6342
Sources Sought (External)	0.1482
Search Investment (Hours/Source)	0.0352
EVALUATION PHASE	
Rejected Elements Processed	0.0720
Accepted Elements Processed	-0.2793
Competency/Reliability (Rejected Elements)	0.4249
Competency/Reliability (Accepted Elements)	-0.0568
Relevance to Task (Rejected Elements)	0.2734
Relevance to Task (Accepted Elements)	-0.3336
Image State Conflict (Rejected Elements)	0.0983
Image State Conflict (Accepted Elements)	0.2110
Evaluation Investment (Hours)	0.3352
INTEGRATION PHASE	
Integration Investment (Hours)	0.2109

appears reasonable from a conceptual point of view. Similarly, in terms of data collection it was extremely difficult for the subjects of the study to clearly distinguish between the two phases with respect to the processing of information elements. There is insufficient evidence to determine whether this was due to the nature of the tasks included in the study or whether the two phases are, in fact, impossible to identify with regard to any task. The tendency of the investigator is to lean toward the former explanation.

SUBGROUPS AS CORRELATES

In the previous section it was indicated that the contributions of individual variables in a set vary considerably. For example, referring to Table II, the Information-Processing Efficiency Index alone might possibly contribute more to the canonical correlation between the independent and dependent sets than a group of the measures with very low correlations with the composite.

Various subgroups of the thirteen measures listed in Table II could be examined in terms of their combined canonical correlation with the dependent set. A particularly promising subgroup consists of the first three measures in Table II: Information-Processing Efficiency; Image State Index, and Task Result Rating. Note that these three independent measures have the highest composite correlations of the original thirteen and one is from each of the individual, task, and individual/task (joint) interaction groups.

The canonical correlation coefficient for this 3 x 13 system of variables is 0.883 and is significant at an alpha level of 0.001. This suggests the existence of a relationship almost as strong as that associated with the original 13 x 13 system of variables.

The square of the canonical correlation coefficient divided by 1.0 can be used as a measure of the proportion of variation "explained" by the variables included in the system. On this basis the three variable group seeks to explain $(0.883)^2$ or 78.4 percent of the variation in the dependent group while the 13 variable group seeks to explain $(0.940)^2$ or 88.3 percent. Thus, the three measures contribute almost as much as does the entire set of thirteen.

The contribution of each of the three variables to the subgroup is indicated by the correlation between each of the three original variables and the composite variable. The composite correlations in both the 3 x 13 and 13 x 13 systems are shown in Table V. Note in the subgroup (3 x 13 system) that Information-Processing Efficiency ranks the same as it did in the 13 x 13 system. However, Task Result and Image State Index change rankings in the two systems.

While various other subgroups could be investigated via canonical analysis, the above variables provided the highest three variable correlation with the dependent set. The addition of the remaining ten independent variables contributes only 10 percent additional.

TABLE V

Composite Correlations for Selected Independent Variables from the 3 x 13 and 13 x 13 Systems

Variable	Composite Correlation	
	3 x 13	13 x 13
Information-Processing Efficiency Index	0.7842	0.7005
Image State Index	0.4580	0.3966
Task Result Rating	0.5047	0.3638

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A NOTE OF PREDICTION

The intent of this exploratory investigation was not prediction. However, considering the results that have been achieved it seems appropriate to outline how the data and relationships resulting from the study might be utilized for predictive purposes. It is important to note in this respect that the following discussion primarily seeks to outline the mechanics of using the data for prediction purposes rather than to suggest that the data obtained in the study should be used in a predictive model.

Since the 3 x 13 variable system is almost as highly correlated as the 13 x 13 system, the subgroup of three independent measures provides a relatively simple predictive set. Using a new individual/task situation (obtained from the research site), measures for the three independent variables discussed in the previous section could be obtained. These could be used to estimate the composite, x^*, by substituting the measures (in standardized form) in the following equation:[5]

$$a_1x_1 + a_2x_2 + a_3x_3 = x^*$$

where the a_i are the canonical weights and

the x_i are the measures in standardized form.

The canonical weights resulting from canonical analysis reflect the relative contribution of each of the original variables to the computation of the composite canonical variables, x^* and y^*. However, these weights can be misleading if used as guides to the nature of the canonical

[5]Measures in standardized form have means equal to zero and standard deviations equal to one.

relationships. Rather the correlations between the original variables and their composites ($r_{x_i x^*}$ and $r_{y_i y^*}$) should be used as guides to the importance of each variable in the canonical system as discussed in the two previous sections. The canonical weights for the independent and dependent variable measures are shown in Appendix N.

Next, the value of y^* could be computed by substituting x^* in $y^* = r_{x^*y^*}(x^*)$ where $r_{x^*y^*}$ is equal to 0.875 for the 3 x 13 variable system. This predicted value could then be compared to the calculated value of y^* by substituting actual measures (in standardized form) in the following equation:

$$b_i\, y_i + b_2\, y_2 + \cdots\cdots + b_{13}\, y_{13} = y^*$$

where the b_i are the canonical weights for the dependent measures and the y_i are the actual variable measures is standardized form.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The purpose of this chapter is to summarize the results of the study and to identify some directions for further research.

SUMMARY

The present study fits into the very broad area of research on information-processing and decision-making. The bulk of research in this general area has been centered on information systems which have been conceived, developed, and implemented to cope with the problems associated with the exponential growth of information.

The individual user of information is a vital element in any information system, formal or informal. The impetus for this study emerged from an apparent neglect or, at best, superficial understanding of the individual's information-processing behavior in the context of problem solving.

The major objective of the study was to conduct an exploratory investigation of individual information-processing during the process of solving technical tasks associated with research and development projects and programs. The effort was intended to seek out the apparently important variables relating to information-processing, the individual, and the task within a given environment; to link these variables into a conceptual analytical structure; and then to investigate the existence of relationships among the variables via a field study.

The study consisted of four separate, but interrelated, phases. The first concerned the identification and evaluation of applicable research foundations. The second phase involved the development of a conceptual system of variables for use in identifying potential relationships and investigating them empirically. The third phase was concerned with developing the specific methodology utilized in the study. The final phase involved the analysis of the data and a discussion of the results obtained from the study.

The results of the research were quite encouraging. The conceptual system of variables appears to be highly associated within the research site utilized in the study. An individual's information-processing efficiency, his image state (state of knowledge) for a particular task, the result rating of the task (in terms of meeting specified objectives and constraints), and the individual's risk-taking propensity appear to impinge rather significantly upon the set of variables in the information-processing domain.

The information-processing variables which made the most significant contributions to the dependent set were number of information sources sought (internal), competency/reliability of rejected elements, evaluation investment, and relevance of accepted elements to task.

The four independent variables which were found to make the most significant contributions to the variable set represented the domains of the individual, the task, and individual/task interaction. Two of the variables (information-processing and risk-taking propensity) represented the domain of the individual suggesting that this domain may be the most important of the three.

In attempting to speculate as to why the results which were achieved came about, it is relevant to consider that several of the independent variables were found in previous research to impinge rather significantly upon the decision-making domain. Conceptually, information-processing is a integral part of a decision process. Thus, a close relationship seems logical between the independent and dependent variables included in the study.

The objectives of the exploratory study appear to have been accomplished in that certain apparently important variables relating to information-processing, the individual, and the task (within the given environment) have been identified. The existence of interrelationships between the independent and dependent variable sets is indicated with certain variables playing rather dominant roles.

The results of the study are not operational in that they can be moved intact to some immediate area of application. Rather, they provide a group of findings that can form a base for further research and development. The current state of knowledge on individual information-processing is limited. This study has provided a modest insight into an extremely complex area. The need for further research is apparent.

SOME DIRECTIONS FOR FURTHER RESEARCH

The findings of this exploratory research provide a springboard for further research in several directions. A number of specific studies and experiments seem potentially worthwhile based on the encouraging results of the study. Further investigation in these areas appears promising: (1) the refinement and extension of certain of the measures of key variables in the system; (2) investigation of relationships among key variables in a controlled laboratory environment; (3) linkage of the results of the study to the user/system interface; (4) investigation of the variable system in other environments; (5) normative extensions; (6) decision process implications; and (7) group information-processing and decision-making. These areas are discussed briefly on the following pages.

Those variables which have been identified as promising correlates of individual information-processing could be investigated further along two related avenues. Single instruments were employed with respect to information-processing efficiency, task result, risk-taking propensity, and image state for the task. The development of additional instruments for the measurement of these variables as well as the refinement of the existing measures seem worthwhile. Before extending the study in additional directions it seems appropriate to refine and extend these instruments to assure to the degree possible that the variation of interest is actually being measured. This could be accomplished as a part of the experiment outlined below, concerning a controlled laboratory investigation.

A second related avenue for further research is an investigation under laboratory conditions of the apparent relationships between the three key independent variables and a selected group of information-processing variables. The findings of the study suggest the existence of relationships which could be investigated via a controlled laboratory experiment. Since the results discussed in Chapter 5 indicate that the potential correlates of individual information-processing may involve only a relatively limited number of variables, investigation within a laboratory environment seems feasible.

The implications of this study are not immediately obvious with regard to their linkage to information systems design. However, the user of information is a central element in any information system. The results of the study should provide benchmarks leading to further investigation of the user/system interface. Recognizing the broad range of systems which are developed for specific applications, the most fruitful direction for further research in the context of the present study seems to be the use of the conceptual system of variables adjusted for a specific user/system situation. For example, the conceptual variable system might be used to investigate the user/system interface for special studies which are conducted with respect to highly specialized information-processing tasks such as weather message processing, console design, and speed stress as discussed in Chapter 2.

The conceptual model of individual information-processing and the associated methodology which was developed for this study provides a frame of reference for similar studies in one or a number of industrial firms. An investigation in terms of limited subsets of the variables in the total system would be necessary in view of the scope and depth of data collection.

The overall approach of the study suggests a basis for similar investigations in other decision-making areas. For example, a better description of individual information-processing and decision-making in regard to consumer decision-making in marketing could provide valuable guidelines for promotional strategy.

The focus of this study has been descriptive in nature. A subsequent effort could be directed toward the normative or predictive usefulness of a model of information-processing and decision-making. Additionally, the normative implications of certain of the explanatory variables may provide useful results. For example, the interrelationships among the independent variables in study may provide avenues which could be explored further in the interest of identifying those characteristics important to improving individual information-processing activities. Confirmation of such relationships could lead to guidelines for personnel selection in situations similar to those of the research site.

Individual information-processing has been investigated in this study assuming constant constraints relative to cost and time. An examination of the same variable system using varying task cost and time constraints appears to be a useful avenue of inquiry. This might be combined with the laboratory experiment discussed earlier.

The analytical framework developed for the study does not attempt to link explicitly information-processing to the specific stages of a decision-process which are frequently referred to as problem identification, information seeking, identification of alternatives, evaluation of alternatives, and final choice. A study utilizing a two dimensional approach of search, evaluation, and integration of information elements on the one hand, and the stages of a decision process on the other hand, could provide a more comprehensive linkage between information-processing and decision-making.

The present research effort has looked at information-processing from the point of view of the individual problem solvers. An examination of the same variable system within the context of group decision activity appears to be a meaningful area for further research.

APPENDIX A

JOB PERFORMANCE RANKING GUIDE

OBJECTIVE

Will you please rank the individuals listed in the left hand column from high to low using the following job performance factors as a basis of comparison of individuals. The factors are not listed in any particular order of importance.

1. Depth of problem solving capability. Number of approaches generated — imagination, ingenuity, generation of feasible alternatives. Ability to select "best" alternative.

2. Degree of success in producing results.

3. Consistency with respect to quality and timeliness.

4. Tenacity and perseverance — attention to details.

5. Communication of results.

PROCEDURE

After carefully considering the above five factors use them as a basis for selecting the individual who ranks at the top of the group. Place his name at the top of the right hand column. Next, select the individual who ranks at the bottom of the group. Write his name at the bottom of the right hand column. Continue, to alternate from next highest to next lowest until all names have been placed in the right column in ranked order from high to low.

Name of Individual	Rank from High to Low
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________
4. ____________	4. ____________
5. ____________	5. ____________
6. ____________	6. ____________
7. ____________	7. ____________
8. ____________	8. ____________
9. ____________	9. ____________
10. ____________	10. ____________
11. ____________	11. ____________
12. ____________	12. ____________
13. ____________	13. ____________
14. ____________	14. ____________
15. ____________	15. ____________
16. ____________	16. ____________
17. ____________	17. ____________
18. ____________	18. ____________

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APPENDIX B

JOB PERFORMANCE RATING

NAME ______________________ PERSON RATING ____________________

DATE ______________________

OBJECTIVE

Will you please rate the above individual on the scale below using the following job performance factors as a basis of comparison of individuals. The factors are not listed in any particular order of importance.

1. Depth of problem solving capability. Number of approaches generated — imagination, ingenuity, generation of feasible alternatives. Ability to select "best" alternative.

2. Degree of success in producing results.

3. Consistency with respect to quality and timeliness.

4. Tenacity and perseverance — attention to details.

5. Communication of results.

PERFORMANCE RATING

Very Low Performance ___ 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 Extremely High Performance

REMARKS

APPENDIX C

CHOICE DILEMMAS PROCEDURE EXAMPLE[1]

Mr. E. is president of a light metals corporation in the United States. The corporation is quite prosperous, and has strongly considered the possibilities of business expansion by building an additional plant in a new location. The choice is between building another plant in the U. S., where there would be a moderate return on the initial investment, or building a plant in a foreign country. Lower labor costs and easy access to raw materials in that country would mean a much higher return on the initial investment. On the other hand, there is a history of political instability and revolution in the foreign country under consideration. In fact, the leader of a small minority party is committed to nationalizing, that is, taking over, all foreign investments.

Imagine that you are advising Mr. E. Listed below are several probabilities or odds of continued political stability in the foreign country under consideration.

Please check the lowest probability that you would consider acceptable for Mr. E's corporation to build a plant in that country.

_____ The chances are 1 in 10 that the foreign country will remain politically stable.

_____ The chances are 3 in 10 that the foreign country will remain politically stable.

_____ The chances are 5 in 10 that the foreign country will remain politically stable.

_____ The chances are 7 in 10 that the foreign country will remain politically stable.

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[1]Nathan Kogan and Mícahel A. Wallach, Risk Taking: A Study in Cognition and Personality (New York: Holt, Rinehart and Winston, 1964), p. 258.

_____ The chances are 9 in 10 that the foreign country will remain politically stable.

_____ Place a check here if you think Mr. E's corporation should <u>not</u> build a plant in the foreign country, no matter what the probabilities.

APPENDIX D

INFORMATION-PROCESSING EFFICIENCY INDEX

Approach

The basic approach in measuring an individual's Information-Processing Efficiency (P_5) for this study was that utilized by Hayes.[1] The reader should refer to the Hayes study for more complete details. The primary modifications to Hayes procedure were as follows:

1. A fixed task was utilized in that decision alternatives were held at eight and the characteristics describing each task were held to eight. Hayes varied both from four, six and eight alternatives and characteristics.

2. The range of values for each characteristic was modified slightly to arrive at task sets A, B, C, and D.

Decision Matrix

A typical data matrix is shown below:

	1	2	3	4	5	6	7	8
Speed	327	387	267	207	267	297	327	297
Pilot	PF	VP	GE	GE	FG	GE	PF	FG
Delay	3	3	3	5	9	3	9	7
Radar	F	F	G	FG	GE	GE	GE	GE
Armament	50%	30%	80%	100%	50%	100%	80%	50%
Distance	150	110	170	250	150	190	210	130
Search	31	36	26	41	26	46	26	26
Contact	F	PF	GE	P	FG	F	FG	G

[1] John R. Hayes, Human Data Processing Limits in Decision Making, Report No. ESD-TDR-62-48 (Bedford, Mass.: Air Force Systems Command, Electronic Systems Division, July, 1962).

The numbers one through eight refer to eight alternative aircraft. The task is to decide which of the alternative planes to send to investigate a reported submarine sighting. The characterisitcs in the left-hand column describe the alternatives. As Hayes indicates:

> "The eight characterisitcs do not share a common unit of measurement nor does an increasing numerical value necessarily indicate an increase in desirability. For example, high numbers are more desirable for "speed," but less desirable for "delay." These properties of the set of characteristics make it unlikely that the subject will adopt a simple arithmetic rule for arriving at decisions and, hence, will help to insure that decisions will involve genuinely multidimensional judgements."[2]

Thirty-two data matrices were constructed using the random technique described by Hayes in Appendix A.[3] Four sets (A, B, C, and D) of eight different matrices were developed. The basic data used to randomly construct each matrix are shown on the next page.[4]

This basic set of data was used to generate the eight decision matrices for set A. Sets B, C, and D were generated by modifying the basic set of data as follows:

1. The values for characteristics 2, 4, 5, and 8 were the same for task sets A, B, C, and D.

2. On task sets B, C, and D the best "speed" value began at 387, 383, and 386, respectively and decreased in increments of 30.

3. On task set B the best "delay" value began at 1 and increased in increments of 2. On set C the best "delay" value began at 0 and increased in increments of 2. On set D the best "delay" value began at 2 and increased in increments of 1.

4. Distance began on sets B, C, and D at 110, 115, and 95, respectively, and increased in increments of 20.

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[2]<u>Ibid</u>., p. 3.

[3]<u>Ibid</u>., pp. 24-27.

[4]<u>Ibid</u>., p. 41.

Characteristic	"Best" Value	Rank of Values						"Worst" Value	Unit of Measurement
	1	2	3	4	5	6	7	8	
1. Speed	375	345	315	285	255	225	195	165	Miles per hour
2. Pilot	E	GE	G	FG	F	PF	P	VP	Adjective
3. Delay	0	2	4	6	8	10	12	14	Minutes
4. Radar	E	GE	G	FG	F	PF	P	VP	Adjective
5. Armament	100%	90%	80%	70%	60%	50%	40%	30%	Percent
6. Distance	100	120	140	160	180	200	220	240	Miles
7. Search	55	49	43	37	31	25	19	13	Minutes
8. Contact	E	GE	G	FG	F	FP	P	VP	Adjective

5. Search began on set B at 46 and decreased in increments of 5. Search began on sets C and D at 53 and 56, respectively, and decreased in increments of 6.

Administration Procedure

Four batteries of eight tasks each were administered individually to each subject. There was a time gap of approximately one week between each battery. The makeup of each battery is shown below:

Battery No.	Matrices Included
1.	A_1 B_2 C_3 D_4 A_2 B_3 C_4 D_5
2.	A_3 B_4 C_5 D_6 A_4 B_5 C_6 D_7
3.	A_5 B_6 C_7 D_8 A_6 B_7 C_8 D_1
4.	A_7 B_8 C_1 D_2 A_8 B_1 C_2 D_3

The instructions given to each subject were essentially the same as those utilized by Hayes and are shown below:[5]

Before testing, each subject was instructed as follows:

"This is an experiment in decision making. You are based at a shore station and you receive reports of radar sightings of submarines. It is your job to dispatch a single plane to search the area where the sighting occurred. To do this you have to decide which one of the available planes is best for the assignment."

"In each problem, you will have eight planes from which you must choose. In making your decision you will have to consider several factors which describe the planes."

At this point the subject was shown a data matrix listing the eight characteristics. Each was explained to him in detail. The subject was

[5]*Ibid.*, pp. 9-10.

then asked to paraphrase the explanations. If the subject's paraphrasing was judged unsatisfactory, the explanation was repeated.

The instructions then continued as follows:

"The problem will be presented to you on these sheets, and will be placed face down in front of you. When I give the signal turn the problem over and start work. When you have finished, tell me which plane you have chosen.

"Each day's test will consist of 8 problems. In each problem, you should try to make the best decision possible; accuracy is the most important thing."

Scoring

The construction of each matrix (using Hayes' procedures) was such that there were one best, one second best, one third best, and four fourth best alternatives. Scores of 1.00, 0.875, 0.750 and 0.625 were given for first, second, third, and fourth best alternatives respectively. These scores correspond to decision quality measures.

The time required by the subject to make a decision on each task was recorded along with the particular alternative selected by him.

An information-processing efficiency (IPE) index was constructed for each subject as follows:

$$\text{IPE Index} = \frac{1}{n} \sum_i \frac{t_i}{q_i}$$

where i goes from 1 to 32,

t_i = time for decision i in minutes,

q_i = quality of decision i,

q_i has alternative values of 1.000, 0.875, 0.750 and 0.625,

and $n = 32$.

APPENDIX E

TASK RECORD
(See instructions on back before completing this form)

RSS NO. ______________________ DATE RECEIVED (T_4) ____________

ASSIGNED TO __________________ DATE CLOSED OUT (T_4) ____________

A. FIELD CODE (T_1) ____________________

B. MAJOR OUTPUT CODE (T_2) ______________

C. KIND OF OUTPUT CODE (T_3) ____________

D. PRECISION OF DEFINITION (T_5):
(Place an X above the number selected)

Well Defined ___ 7 ___ 6 ___ 5 ___ 4 ___ 3 ___ 2 ___ 1 Poorly Defined

E. SCOPE AND COMPLEXITY (T_6):
(Place an X above the number selected)

Low Difficulty ___ 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 High Difficulty

TECHNICAL MAN-HOURS EXPENDED (Estimated) ____________

F. RESULTS (T_7):
(Place an X above the number selected)

Results Very Good ___ 7 ___ 6 ___ 5 ___ 4 ___ 3 ___ 2 ___ 1 Negative Results

G. REMARKS

INSTRUCTIONS FOR COMPLETING TASK RECORD

A. Field Code. Indicate the code number in the appropriate field for the task using the ARAC retrospective search classification codes.

B. Major Output Code

1. Finding
2. Recommendation
3. Decision
4. Other

C. Kind of Output Code

1. Research
2. Exploratory Development, Advanced Development, Engineering Development, and Operational Systems Development
3. Reliability - Quality Control - Manufacturing
4. R&D Support
5. Engineering Design
6. Other

D. Precision of Definition. A well defined task is one where the objectives and constraints are completely specified. Further contact with the originator of the task is unnecessary. A poorly defined task is one where the problem solver does not know what is required in terms of objectives and constraints.

E. Scope and Complexity. A task reflecting high difficulty is one on which the problem solver has no basis for knowing where to start in it. It is so complex that it requires custom tailored treatment. In contrast, a low difficulty task is one where a clear-cut procedure for gaining a solution is known.

F. Results. Results should be evaluated in terms of the task objectives and constraints. Very good results would be reflected in terms of the degree to which positive statements can be made regarding the solution using the objectives and constraints as a base of reference.

G. Remarks. Indicate any additional comments that may be helpful in characterizing the task and distinguishing it with respect to other tasks. Note unusual characteristics of the task.

APPENDIX F

TASK FIELD CLASSIFICATION SYSTEM[1]

01 Aerodynamics
02 Aircraft
03 Auxiliary Systems (Energy Supply Systems)
04 Biosciences
05 Biotechnology (Human Engineering)
06 Chemistry
- a. Organic (Includes Polymerizations)
- b. Inorganic
- c. Unit Operations and Processing

07 Communications
08 Computers
09 Electronic Equipment
10 Electronics (Theory)
11 Facilities (Building & Construction)
12 Fluid Mechanics
13 Geophysics (Atmosphere & Air Pollution Studies)
14 Instrumentation and Photography
15 Machine Elements and Processes
- a. Bearings and Lubrication
- b. Machining
- c. Metal Forming
- d. Seals
- e. Valves
- f. Joining
- g. Mechanisms

16 Masers and Lasers
17 Materials, Metallic
- a. Corrosion
- b. Metallurgy
- c. Plating & Coatings
- d. General

18 Materials, Non-Metallic
- a. Adhesives
- b. Ceramics
- c. Plastic
- d. Reinforced Plastic
- e. Rubber
- f. Paints and Coatings

19 Mathematics
20 Meterology
21 Navigation
22 Nuclear Engineering
23 Physics, General
24 Physics; Atomic, Molecular and Nuclear
25 Physics, Plasma
26 Physics, Solid State (Semiconductors)
27 Propellants
28 Propulsion Systems (Engines & Turbines)
29 "Space Radiation" (Radiation Effects, Control of Environment)
30 Space Sciences
31 Space Vehicles
32 Structural Mechanics
- a. Fatigue
- b. Stress Analysis
- c. Vibration
- d. Testing

33 Thermodynamics and Combustion
34 General
- a. Information Retrieval
- b. Quality Control and Reliability
- c. Management and Marketing

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[1]Provided by the Aerospace Research Applications Center, Indiana University, Bloomington, Indiana.

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APPENDIX G

SEARCH RECORD

(See instructions on back before completing this form)

RSS NO. ____________________ DATE RECEIVED ____________________

NAME ____________________ DATE COMPLETED ____________________

A. SOURCE ALTERNATIVES (J_1)

Alternative sources from which you anticipate obtaining information relevant to this task. (List as they occur to you)	Probability Estimates. (The sum of each column can exceed 1.0) Does the source contain some relevant information? (q_i)	If there, how helpful will it be? (r_i)
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________

B. INTEREST IN TASK (J_2)

Considering the various RSS's that you have worked on, how does your interest in this task compare with them.

(Place an X above the number selected)

Very Low Interest ___ 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 Extremely High Interest

C. CERTAINTY OF OUTCOME (J_3)

What is your probability estimate concerning the likelihood that you will come up with a solution to the task in terms of the objectives and constraints given for the task?

___ 0 ___ .1 ___ .2 ___ .3 ___ .4 ___ .5 ___ .6 ___ .7 ___ .8 ___ .9 ___ 1.0

D. TASK LOAD (J_4)

How many other RSS's are you currently working on? Indicate No.___

INSTRUCTIONS FOR COMPLETING SEARCH RECORD

A. SOURCE ALTERNATIVES

Please list all possible sources that you believe may contain information relevant to this task. Include such sources as your associates, other individuals (including the person submitting the request), reference books, information systems, etc. These sources are in effect alternatives that you see as avenues through which you can gain a solution to the task.

Probability Estimates. Under column q_i indicate the probability (between 0.0 and 1.0) that each source contains some relevant information -- not how much or how good it may be. Under column r_i indicate the probability (between 0.0 and 1.0) that if the source does contain some information, then how helpful will it be. This is your probability estimate of the degree of help.

B. INTEREST IN TASK

Be frank in your indication of interest on this task. If it is of marginal interest to you, then indicate this on the form. If it is of high interest check the form accordingly. Consider other problems you have worked on and try to view your interest in this problem in terms of the others you have worked on.

C. CERTAINTY OF OUTCOME

On some problems you are relatively sure that you will locate relevant information. On others the existence of such information is highly doubtful. Try to objectively estimate the probability of success concerning the outcome of the task that you have been assigned. In other words, how certain are you concerning the outcome of the task in terms of the specified objectives and constraints?

D. TASK LOAD

Indicate here how many other RSS's you are working on at the time of receipt of this task.

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APPENDIX H

DIARY OF INFORMATION SOURCES*
(See instructions on back before completing this form)

NAME ____________________ RSS NO. __________

(A) LIST IN ORDER SOURCE IS SEARCHED	(B) SOURCE CODE NO. (I_1)	(C) IDENTIFY (I_1)	(D) ESTIMATED TIME SPENT (I_2)	(E) DATE
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

*Information resulting from your existing knowledge (that contained in your head) is not to be considered in terms of a source. Rather it is characterized by your "image state" for the task at the outset of the task.

INSTRUCTIONS FOR DIARY OF INFORMATION SOURCES

A. List each source in the order that you begin searching. If you refer more than once to the same source, list it each time in the order it is utilized. People are sources the same as books, computer systems, etc.

B. and C. Identify each source classification in column B by using the following code numbers. Also identify the specific name of the source (i.e. NASA, John Smith, DOD, AEC, Science Information Exchange, etc.) in column C.

SOURCES SOUGHT:

Code No.	Internal	Code No.	External
1.	Supervisor	9.	Library
2.	Colleague	10.	Organized Information System
3.	Other Individual		
4.	Organizational Files	11.	Consultant
5.	Personal Files	12.	Manufacturer or Supplier
6.	Library		
7.	Organized Information System (Manual or Computerized)	13.	Trade or Professional Association
		14.	Other (Identify)
8.	Other (Identify)		

D. Estimate the time (in hours and fractions thereof) spent in searching each source.

"Search" is defined as that portion of your effort up to the point that you have received one or more "elements" of information. For example, the time spent in writing a computer search strategy should be considered as search time. When you begin to evaluate information received the time should be entered in the "Diary of Information Elements."

E. Indicate the date search was initiated for each source (if search of a particular source is extended over one day provide a new listing each day). Also enter any sources that are contacted after initial contact. Try to record a play-by-play listing of the sources you contact on the task.

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APPENDIX I

DIARY OF INFORMATION ELEMENTS (Received and Evaluated)
(See Instructions for Columns A–M)

I_5 (A) Element Number	(B) Date	(C) Source Number	I_3 (D) Channel/ Media Code	I_4 (E) Element Type Code	I_6 (F) COMPETENCY/ RELIABILITY Low 1 2 3 4 5 6 7 High
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					

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APPENDIX I (Continued)

RSS NUMBER ________________

I_7							I_8							I_9	
(G) RELEVANCE TO TASK							(H) IMAGE STATE CONFLICT							(I)	(J)
High						Low	Low						High	Evaluation Time (Estimated)	Accept/ Reject (A or R)
7	6	5	4	3	2	1	1	2	3	4	5	6	7		

APPENDIX I (Continued)

NAME ____________________

(K) Prescriptive (Yes or No)	I_{11} (L) CONTRIBUTION TO RESULT High 7 6 5 4 3 2 1 Low	I_{12} (M) Time Spent After Accept-Reject Decision

a
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INSTRUCTIONS FOR DIARY OF INFORMATION ELEMENTS (Received and Evaluated)

An information element is defined such that if you receive 25 accession numbers on a computer print-out, each of the 25 is considered an information element. Information resulting from a discussion with an associate is defined as an element of information.

A. and B. ELEMENT NUMBER AND DATE

List each information element in the order it is received by you. Indicate the date of receipt. Typically an element will be received as a result of search action initiated by you. However, if it comes to your attention not as a result of search then it should be noted as random.

C. SOURCE NUMBER

Obtain the source number from the left hand column number on the Diary of Information Sources. This links the source with the information element received.

D. CHANNEL/MEDIA CODE NUMBER

The channel or media is the means by which the information element is transmitted to you. Use the code number on the next page to identify the appropriate channel/media.

E. ELEMENT TYPE CODE NUMBER

Use the code number on the next page to identify the element type.

F. COMPETENCY/RELIABILITY

Your evaluation of the competency/reliability of a particular information element should be based on the source of the information element. For example, if you consider the source highly reliable then this rating should be relatively high. Alternatively, mark it low if your evaluation indicates this.

G. RELEVANCE TO TASK

Indicate the degree of relevancy the information element has with respect to the task according to the rating scale on the form.

H. IMAGE STATE CONFLICT

Consider the information element's influence on your present state of knowledge concerning the task. If the element has a high conflict with your current "image state" then you should indicate this via the rating scale.

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I. EVALUATION TIME

At this point you will have accepted or rejected the information element. Estimate the amount of time spent in evaluating the element.

J. ACCEPT/REJECT

Indicate your decision to accept or reject this information element.

The following columns should be completed only for "accepted" elements. No further information is required on "rejected" elements.

K. PRESCRIPTIVE

Indicate if the element is prescriptive (yes or no). Prescriptive information has a mandatory effect on the task with respect to objectives and/or constraints. The bulk of information received is of a non-prescriptive nature.

L. CONTRIBUTION TO RESULT

Use the rating scale in column L to rate the contribution of the information element to the final result of the problem. Attempt to make this rating at the time of your accept/reject decision. Additionally, go back over your ratings at the completion of the task.

M. TIME SPENT AFTER EVALUATION

Estimate the amount of time spent on each information element after your decision to accept/reject the element up to completion of the task.

Code	CHANNEL/MEDIA (I_3)	Code	ELEMENT TYPE (I_4)
1	Brochures, catalogs, standards and codes, drawings, schematics, and parts lists.	1	Concepts.
		2	Cost and funding.
2	Oral contact.	3	Design techniques.
3	Live demonstration, physical measurement of experiment.	4	Experimental processes.
		5	Mathematical aids and formulae.
4	Directives, handbooks, and manuals.	6	Performance and characteristics.

Code	CHANNEL/MEDIA (I_3)
5	Correspondence, memos, TWX, personal notes, personal logs, and personal files.
6	Newsletters and other mass media.
7	Reports and proposals.
8	Texts.
9	Photographs, maps, and films
10	Pre-prints, reprints, and journals.
11	Previous knowledge.
12	Computer printout.
13	Other.

Code	ELEMENT TYPE (I_4)
7	Production processes and procedures.
8	Raw data.
9	Specifications.
10	Technical status.
11	Test processes and procedures.
12	Utilization.
13	Other.

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APPENDIX J

DATA USED IN THE STUDY

The empirical data collected in the study are presented on the following pages in Appendices J-1, J-2, J-3, J-4, and J-5. The numbers for each measure correspond to those in Table I, Chapter 5 and Appendix M.

APPENDIX J-1

Data Obtained on Subjects
for the Ten Individual Measures

Subject Number	Individual Measures									
	1	2	3	4	5	6	7	8	9	10
1.	0.30	0.55	14.3	3.7	495.	27.	31.	31.	83.	0.592
2.	0.25	1.90	12.0	4.3	516.	27.	34.	31.	76.	0.952
3.	0.18	2.68	8.0	4.7	610.	36.	39.	42.	68.	3.170
4.	0.25	0.25	7.9	5.3	643.	37.	43.	42.	68.	1.365
5.	0.55	0.55	1.7	6.0	524.	29.	34.	36.	90.	0.431
6.	1.25	4.50	6.3	5.0	510.*	26.*	32.*	34.	68.	1.493
7.	0.25	2.25	8.7	4.3	482.	27.	29.	34.	72.	1.888
8.	0.85	3.10	7.3	5.0	457.	20.	33.	38.	52.	0.538
9.	1.15	2.65	2.7	5.7	630.*	34.*	40.*	42.	58.	2.937
10.	0.85	1.85	17.7	3.3	594.	36.	36.	40.	69.	0.596
11.	0.40	1.40	13.0	3.3	540.*	28.*	34.*	36.	62.	1.691
12.	0.85	1.60	13.7	4.0	615.	43.	33.	37.	75.	1.813
13.	0.25	1.00	4.0	5.0	602.	40.	33.	40.	64.	0.598
14.	0.18	8.68	11.3	4.3	364.	11.	29.	25.	66.	1.704
15.	0.10	0.35	13.7	3.7	551.	32.	34.	38.	83.	0.520
16.	0.85	1.60	3.7	6.0	428.	21.	28.	35.	56.	1.930
17.	0.85	1.10	15.7	3.0	601.	30.	43.	41.	82.	0.823
18.	0.85	1.35	4.7	5.3	516.	27.	34.	32.	80.	1.031

*Estimated.

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APPENDIX J-2

Measurements Obtained for Independent Variables in Phase A of Study

Task Number	Subject Number[1]	Independent Variable Measurement								
		Task					Joint			
		11	12	13	14	15	16	17	18	19
1	7	7.0	5.0	4.0	5.50	5.0	0.712	3.5	0.6	2.0
2	10	14.0	2.0	4.0	8.75	4.0	1.952	3.5	0.6	2.0
3	10	23.0	3.0	4.0	21.25	3.0	1.952	2.5	0.6	3.0
4	13	18.0	2.0	5.0	7.75	4.0	1.308	3.5	0.5	1.0
5	18	16.0	4.0	4.0	1.00	5.0	1.662	4.0	0.3	1.0
6	2	6.0	4.0	5.0	7.50	4.0	1.354	4.5	0.9	4.0
7	5	7.0	4.0	4.0	6.75	5.0	0.932	6.0	0.9	2.0
8	1	9.0	4.0	4.0	16.25	4.0	0.893	6.0	0.9	1.0
9	7	14.0	6.0	4.0	22.25	5.0	1.615	5.5	0.5	1.0
10	13	7.0	6.0	5.0	5.50	5.0	0.887	5.0	0.7	3.0
11	8	9.0	4.0	4.0	3.50	5.0	1.155	4.0	0.8	2.0
12	12	15.0	3.0	5.0	4.00	4.0	1.749	5.0	0.4	3.0
13	11	17.0	4.0	4.0	14.50	4.0	1.846	5.0	0.3	2.0
14	6	14.0	4.0	5.0	1.75	5.0	0.587	5.0	0.8	3.0
15	8	16.0	5.0	4.0	4.00	4.0	0.645	4.5	0.9	3.0
16	2	11.0	3.0	3.0	7.00	4.0	2.007	5.0	0.7	1.0
17	3	12.0	3.0	5.0	10.00	5.0	0.952	5.5	0.9	2.0
18	3	21.0	4.0	4.0	3.00	5.0	0.890	4.0	0.6	3.0
19	18	9.0	4.0	4.0	0.75	4.0	0.888	4.5	0.7	2.0
20	4	8.0	4.0	5.0	1.75	4.0	1.269	6.0	0.2	2.0
21	17	6.0	4.0	4.0	5.00	4.0	1.426	3.5	0.9	1.0
22	2	25.0	4.0	5.0	6.75	4.0	2.066	5.5	0.5	3.0
23	14	19.0	4.0	5.0	2.00	3.0	1.613	4.5	0.6	1.0
24	16	17.0	4.0	4.0	16.25	6.0	2.714	5.0	0.3	1.0
25	6	2.0	1.0	5.0	1.00	4.0	1.092	4.5	0.2	2.0

[1] Refer to Appendix J-1 for measurements 1 through 10 corresponding to each subject.

APPENDIX J-3

Measurements Obtained for Independent Variables in Phase B of Study

Task Number	Subject Number[2]	Independent Variable Measurement								
		Task					Joint			
		11	12	13	14	15	16	17	18	19
26	9	29.0	4.0	4.0	8.50	5.0	0.959	4.0	0.9	2.0
27	5	9.0	3.0	4.0	3.50	4.0	0.835	6.5	0.8	1.0
28	2	10.0	5.0	3.0	6.25	5.0	1.899	3.5	0.7	4.0
29	15	10.0	5.0	4.0	7.50	5.0	2.168	5.5	0.9	3.0
30	17	24.0	4.0	5.0	7.75	4.0	1.068	4.0	0.2	1.0
31	3	14.0	5.0	4.0	4.75	5.0	0.441	5.0	9.0	5.0
32	5	7.0	4.0	4.0	2.75	4.0	0.742	6.5	0.8	2.0
33	6	6.0	5.0	4.0	4.75	5.0	0.644	5.0	0.6	3.0
34	12	24.0	3.0	5.0	11.75	5.0	0.977	5.0	0.8	2.0
35	13	16.0	3.0	5.0	10.00	6.0	0.971	6.0	0.5	2.0
36	2	17.0	4.0	4.0	7.75	5.0	2.439	5.0	0.8	4.0
37	3	10.0	4.0	4.0	6.25	4.0	1.318	6.0	0.8	5.0
38	7	15.0	4.0	5.0	12.50	5.0	1.041	5.0	0.7	6.0
39	17	10.0	4.0	4.0	6.25	4.0	0.820	4.5	0.7	2.0
40	16	15.0	5.0	6.0	8.50	5.0	1.460	3.0	0.1	2.0

[2] Refer to Appendix J-1 for measurements 1 through 10 corresponding to each subject.

APPENDIX J-4

Measurements Obtained for Dependent Variables in Phase A of Study

Dependent Variable Measurement	Task Number							
	1	2	3	4	5	6	7	8
1	5.	2.	4.	4.	7.	5.	3.	9.
2	5.	1.	3.	4.	7.	4.	3.	8.
3	0.	1.	1.	0.	0.	1.	0.	1.
4	0.904	0.167	0.667	1.25	2.25	1.083	0.667	4.083
5	0.181	0.083	0.167	0.312	0.321	0.217	0.222	0.454
6	14.	108.	196.	72.	22.	85.	96.	384.
7	4.	57.	131.	29.	18.	41.	69.	0.
8	10.	51.	65.	43.	4.	44.	27.	384.
9	4.22	4.93	4.58	4.00	5.10	5.17	7.00	6.97
10	4.00	4.72	4.49	4.00	5.00	5.48	7.00	0.0
11	4.30	5.14	4.77	4.00	5.50	4.50	7.00	6.97
12	4.22	3.45	2.94	2.44	1.77	3.94	2.92	2.27
13	2.25	2.02	1.71	1.00	1.00	2.39	1.58	0.0
14	5.00	5.07	5.43	3.42	5.25	5.39	6.33	2.27
15	2.00	1.85	1.14	2.00	1.00	1.21	1.00	1.15
16	2.00	1.65	1.05	2.00	1.00	1.20	1.00	0.0
17	2.00	2.06	1.34	2.00	1.00	1.23	1.00	1.15
18	.905	1.325	1.308	1.200	.805	4.000	.600	1.742
19	.039	.014	.005	.017	.026	.031	.005	0.000
20	.075	.015	.009	.017	.086	.062	.010	.005
21	.712	1.952	1.952	1.308	1.662	1.354	0.932	.893
22	4.60	5.00	5.44	3.74	4.75	5.23	5.22	1.34
23	.433	1.500	0.0	0.0	0.0	.517	.517	.833
24	.043	.029	0.0	0.0	0.0	.017	.019	.002

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APPENDIX J-4 (Continued)

Dependent Variable Measurement	Task Number							
	9	10	11	12	13	14	15	16
1	5.	2.	11.	5.	7.	4.	2.	8.
2	4.	2.	9.	4.	7.	2.	2.	7.
3	1.	0.	2.	1.	0.	2.	0.	1.
4	9.300	1.500	1.833	1.733	1.400	.667	.667	1.500
5	1.860	.750	.167	.347	.200	.167	.333	.187
6	168.	163.	12.	82.	95.	4.	264.	48.
7	66.	50.	4.	67.	81.	0.	242.	23.
8	102.	93.	8.	15.	14.	4.	22.	25.
9	4.26	4.00	4.92	3.67	4.98	5.75	4.05	5.32
10	4.25	4.00	4.00	2.96	4.85	0.0	1.00	5.26
11	4.28	4.00	5.37	6.87	5.78	5.75	4.32	5.36
12	3.47	2.94	4.25	1.64	1.59	5.50	4.42	3.60
13	1.62	1.00	2.25	1.02	1.00	0.0	1.00	1.78
14	4.65	4.47	5.25	2.34	5.00	5.50	4.73	5.28
15	2.00	2.00	2.75	1.27	1.14	1.00	1.17	1.17
16	2.00	2.00	4.00	1.06	1.00	0.0	1.00	1.04
17	2.00	2.00	2.12	2.33	1.93	1.00	1.18	1.28
18	4.533	1.333	1.250	1.188	3.933	2.500	2.683	3.917
19	.017	.008	.084	.049	.005	0.0	.002	.052
20	.033	.008	.114	.057	.178	.625	.098	.109
21	1.615	.887	1.155	1.749	1.846	.587	.645	2.007
22	4.65	4.56	3.50	3.60	4.00	4.50	4.68	4.93
23	1.167	0.0	.333	.250	.350	0.0	0.0	.204
24	.011	0.0	.042	.017	.025	0.0	0.0	.008

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APPENDIX J-4 (Continued)

Dependent Variable Measurement	Task Number								
	17	18	19	20	21	22	23	24	25
1	10.	6.	1.	2.	4.	2.	7.	17.	3.
2	9.	6.	1.	1.	2.	2.	7.	14.	1.
3	1.	0.	0.	1.	2.	0.	0.	3.	2.
4	6.083	2.683	1.000	.584	2.750	1.000	7.250	3.188	.667
5	.608	.447	1.000	.292	.658	.500	1.036	.187	.222
6	188.	71.	47.	26.	36.	74.	215.	83.	3.
7	164.	56.	34.	14.	4.	44.	207.	58.	0.
8	24.	15.	13.	12.	32.	30.	8.	25.	3.
9	5.62	5.80	5.00	5.00	4.72	5.22	3.14	4.85	6.00
10	5.61	5.83	5.00	5.28	4.72	4.82	3.00	6.12	6.00
11	5.67	5.72	5.00	4.66	4.72	5.80	4.88	4.10	6.00
12	1.31	1.35	1.89	3.73	4.16	2.99	1.44	3.46	6.00
13	1.00	1.00	1.00	2.15	2.75	1.41	1.00	2.93	6.00
14	3.54	2.71	4.23	5.58	4.34	5.30	6.75	3.88	6.00
15	1.05	1.00	1.00	1.27	1.00	1.03	2.00	1.53	1.00
16	1.00	1.00	1.00	1.14	1.00	1.02	2.00	1.00	1.00
17	1.29	1.00	1.00	1.42	1.00	1.03	2.00	1.80	1.00
18	2.775	1.750	.161	.333	1.500	1.483	2.417	9.564	.250
19	.045	.024	.001	.017	.044	.014	.011	.026	0.0
20	.016	.027	.009	.008	.025	.029	.025	.322	.081
21	.952	.890	.888	1.269	1.426	2.066	1.613	2.714	1.092
22	3.00	2.33	4.46	4.42	4.28	4.50	6.00	3.75	4.00
23	.075	0.0	0.0	.333	0.0	.250	.133	5.785	0.0
24	.003	0.0	0.0	.028	0.0	.083	.017	.231	0.0

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APPENDIX J-5

Measurements Obtained for Dependent Variables in
Phase B of Study

Dependent Variable Measurement	Task Number						
	26	27	28	29	30	31	32
1	14.	1.	8.	7.	5.	7.	2.
2	8.	1.	7.	6.	3.	5.	1.
3	6.	0.	1.	1.	2.	2.	1.
4	3.417	.500	1.750	6.416	3.250	2.333	.333
5	.244	.500	.219	.917	.650	.333	.166
6	99.	93.	84.	416.	10.	42.	68.
7	74.	33.	56.	346.	4.	34.	8.
8	25.	60.	28.	70.	6.	8.	60.
9	4.98	7.00	4.81	5.17	4.80	5.88	7.00
10	4.65	7.00	4.45	5.13	4.00	5.94	7.00
11	5.96	7.00	5.55	5.43	5.33	5.50	7.00
12	1.99	4.46	2.78	2.06	4.60	1.52	5.34
13	1.09	1.60	1.61	1.53	2.25	1.00	1.50
14	4.72	6.03	5.15	4.73	6.17	3.75	5.85
15	1.10	1.00	1.04	1.32	1.00	1.00	1.00
16	1.00	1.00	1.00	1.26	1.00	1.00	1.00
17	1.40	1.00	1.10	1.63	1.00	1.00	1.00
18	2.500	0.567	3.000	6.550	1.000	4.584	2.820
19	.014	.001	.032	.011	.100	.126	.002
20	.060	.009	.044	.031	.100	.028	.047
21	.959	.835	1.899	2.168	1.068	.441	.742
22	3.04	5.70	3.72	4.03	4.66	2.62	5.85
23	.850	.533	.144	2.233	1.00	.500	.283
24	.034	.009	.005	.032	.166	.064	.005

APPENDIX J-5 (Continued)

Dependent Variable Measurement	Task Number							
	33	34	35	36	37	38	39	40
1	7.	5.	10.	8.	6.	5.	5.	15.
2	3.	3.	0.	5.	6.	5.	5.	10.
3	4.	2.	10.	3.	0.	0.	0.	5.
4	.500	.750	.367	.690	4.270	1.916	3.250	8.125
5	.071	.150	.037	.085	.711	.383	.650	.542
6	8.	181.	10.	62.	107.	117.	18.	248.
7	1.	144.	0.	47.	75.	81.	16.	223.
8	7.	37.	10.	15.	32.	36.	2.	25.
9	6.50	3.88	5.00	5.03	5.72	4.15	5.16	4.95
10	6.00	3.73	0.00	5.06	5.60	4.17	5.12	4.00
11	6.58	4.46	5.00	4.82	5.93	4.08	5.50	5.31
12	6.00	2.04	4.50	2.22	1.91	2.95	2.44	4.88
13	1.00	1.30	0.0	1.28	1.31	1.98	1.88	1.40
14	6.72	4.92	4.50	5.12	3.75	5.14	7.00	6.07
15	1.00	1.26	1.00	1.00	1.00	2.00	1.00	2.83
16	1.00	1.08	0.0	1.00	1.00	2.00	1.00	3.00
17	1.00	1.92	1.00	1.00	1.00	2.00	1.00	2.77
18	.600	3.800	10.000	2.333	3.000	1.367	.833	7.125
19	.050	.020	0.0	.028	.028	.008	.046	.014
20	.078	.020	1.000	.068	.029	.017	.046	.160
21	.644	.977	.971	2.439	1.318	1.041	.820	1.460
22	6.58	3.81	4.00	4.73	3.47	5.19	4.50	6.00
23	0.0	0.0	0.0	0.0	0.0	.600	.167	0.0
24	0.0	0.0	0.0	0.0	0.0	.017	.083	0.0

APPENDIX K-1

Correlation Matrix of Independent Variables

Independent Variable Measurement	1	2	3	4	5	6	7	8	9	10
1. ARAC Experience	1.000	0.169	-.076	0.111	-.042	-.140	0.029	0.074	-.147	-.106
2. Total Experience		1.000	-.003	0.020	-.448	-.491	-.268	-.363	-.410	0.360
3. Performance Rank			1.000	-.944	0.197	0.104	0.287	-.012	0.185	-.125
4. Performance Index				1.000	-.267	-.162	-.318	-.078	-.190	0.116
5. ATGSB Total Score					1.000	0.911	0.757	0.777	0.156	0.173
6. ATGSB Verbal Score						1.000	0.438	0.666	0.123	0.150
7. ATGSB Quantitative Score							1.000	0.673	0.215	0.122
8. Wonderlic Score								1.000	-.195	0.240
9. Risk-Taking Propensity Index									1.000	-.359
10. Information-Processing Efficiency Index										1.000
11. Task Time Span (days)										
12. Precision of Definition Rating										
13. Scope and Complexity Rating										
14. Technical Man-hours Invested										
15. Result Rating										
16. Image State Index										
17. Interest in Task Rating										
18. Probability Estimate (outcome)										
19. Ordinal Position of Task										

APPENDIX K-1 (Continued)

Independent Variable Measurement	11	12	13	14	15	16	17	18	19
1. ARAC Experience	0.052	-.238	0.064	-.161	-.025	-.171	-.322	-.195	-.239
2. Total Experience	0.102	-.024	0.133	-.229	-.154	-.097	-.186	0.068	0.101
3. Performance Rank	0.176	-.117	-.127	0.311	-.442	0.378	-.310	-.025	0.079
4. Performance Index	-.147	0.072	0.114	-.318	0.389	-.237	0.300	0.012	-.059
5. ATGSB Total Score	0.151	-.257	0.028	-.013	-.033	-.185	0.041	0.181	0.130
6. ATGSB Verbal Score	0.146	-.270	0.132	0.110	0.094	0.134	0.106	0.148	0.164
7. ATGSB Quantitative Score	0.081	-.123	-.143	-.223	-.248	-.175	-.036	0.196	0.027
8. Wonderlic Score	0.120	-.095	0.062	0.042	0.115	-.296	-.056	0.214	0.078
9. Risk-Taking Propensity Index	-.280	-.066	-.238	-.116	-.236	-.047	0.349	-.014	-.107
10. Information-Processing Efficiency Index	0.260	0.099	0.117	0.045	0.256	-.142	-.008	0.328	0.308
11. Task Time Span (days)	1.000	-.082	0.171	0.332	0.012	0.244	-.263	-.016	-.033
12. Precision of Definition Rating		1.000	-.163	0.076	0.322	-.110	0.060	0.196	0.232
13. Scope and Complexity Rating			1.000	-.069	-.000	-.167	0.000	-.155	0.025
14. Technical Man-hours Invested				1.000	0.107	0.360	-.040	-.085	-.056
15. Result Rating					1.000	-.051	0.138	0.118	0.138
16. Image State Index						1.000	-.172	-.295	-.083
17. Interest in Task Rating							1.000	0.080	0.049
18. Probability Estimate (outcome)								1.000	0.382
19. Ordinal Position of Task									1.000

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APPENDIX K-2

Correlation Matrix of Dependent Variables

Dependent Variable Measurement	1	2	3	4	5	6	7	8
1. Total Sources	1.000	0.845	0.574	0.455	-.136	0.144	0.170	0.024
2. Internal Sources		1.000	0.048	0.538	0.022	0.265	0.261	0.102
3. External Sources			1.000	0.025	-.288	-.138	-.081	-.112
4. Total Search Hours				1.000	0.741	0.524	0.506	0.202
5. Average Hours/Source					1.000	0.351	0.292	0.184
6. Number of Elements						1.000	0.774	0.615
7. Number "Rejected"							1.000	-.022
8. Number "Accepted"								1.000
9. Competency/Reliability - Total								
10. Competency/Reliability - Rejected								
11. Competency/Reliability - Accepted								
12. Relevance - Total								
13. Relevance - Rejected								
14. Relevance - Accepted								
15. Image State Conflict - Total								
16. Image State Conflict - Rejected								
17. Image State Conflict - Accepted								
18. Total Evaluation Hours								
19. Average Hours/Rejected Element								
20. Average Hours/Accepted Element								
21. Change in Image State Index								
22. Contribution to Result								
23. Total Integration Hours								
24. Average/Accepted Element								

APPENDIX K-2 (Continued)

Dependent Variable Measurement	9	10	11	12	13	14	15	16
1. Total Sources	-.048	-.096	-.034	-.126	-.091	-.165	0.267	0.159
2. Internal Sources	-.090	0.071	-.051	-.365	-.044	-.227	0.327	0.287
3. External Sources	0.049	-.289	0.015	0.323	-.104	0.040	-.003	-.143
4. Total Search Hours	-.191	-.049	-.085	-.277	-.094	-.096	0.374	0.299
5. Average Hours/Source	-.231	0.012	-.170	-.251	-.062	-.071	0.195	0.198
6. Number of Elements	-.092	-.261	-.021	-.305	-.270	-.246	0.211	0.050
7. Number "Rejected"	-.324	-.068	-.173	-.299	-.143	0.006	0.229	0.202
8. Number "Accepted"	0.271	-.328	0.196	-.108	-.246	-.396	0.037	-.184
9. Competency/Reliability - Total	1.000	0.351	0.745	0.269	-.001	0.094	-.473	-.401
10. Competency/Reliability - Rejected		1.000	0.188	-.071	0.464	0.250	-.153	0.167
11. Competency/Reliability - Accepted			1.000	0.059	-.140	0.041	-.438	-.347
12. Relevance - Total				1.000	0.387	0.495	0.100	0.057
13. Relevance - Rejected					1.000	0.307	0.081	0.241
14. Relevance - Accepted						1.000	0.054	0.181
15. Image State Conflict - Total							1.000	0.891
16. Image State Conflict - Rejected								1.000
17. Image State Conflict - Accepted								
18. Total Evaluation Hours								
19. Average Hours/Rejected Element								
20. Average Hours/Accepted Element								
21. Change in Image State Index								
22. Contribution to Result								
23. Total Integration Hours								
24. Average/Accepted Element								

APPENDIX K-2 (Continued)

Dependent Variable Measurement	17	18	19	20	21	22	23	24
1. Total Sources	0.273	0.631	0.218	0.304	0.289	-.281	0.428	0.322
2. Internal Sources	0.343	0.391	0.239	-.076	0.370	0.323	0.466	0.359
3. External Sources	-.017	0.580	0.042	0.686	-.028	-.031	0.087	0.052
4. Total Search Hours	0.353	0.347	0.079	-.146	0.177	-.109	0.205	0.085
5. Average Hours/Source	0.142	-.005	-.044	-.282	0.028	0.007	0.045	-.008
6. Number of Elements	0.309	0.261	-.350	-.255	0.163	-.142	0.171	-.177
7. Number "Rejected"	0.368	0.341	-.227	-.175	0.241	0.107	0.123	-.109
8. Number "Accepted"	0.019	-.009	-.267	-.182	-.037	-.363	0.122	-.141
9. Competency/Reliability - Total	-.608	-.098	-.040	0.013	-.303	-.065	-.005	-.073
10. Competency/Reliability - Rejected	-.161	-.189	0.195	-.537	0.157	0.236	0.170	0.173
11. Competency/Reliability - Accepted	-.376	-.229	-.003	-.060	-.216	-.081	-.168	-.148
12. Relevance - Total	-.108	0.013	-.072	0.345	-.242	0.495	-.009	0.032
13. Relevance - Rejected	0.019	-.156	0.096	-.251	0.192	0.146	0.235	0.276
14. Relevance - Accepted	-.105	-.164	-.051	0.013	-.052	0.781	-.142	0.071
15. Image State Conflict - Total	0.859	0.130	0.019	-.082	0.110	0.179	0.119	0.019
16. Image State Conflict - Rejected	0.708	-.077	0.212	-.321	0.094	0.238	-.010	0.011
17. Image State Conflict - Accepted	1.000	0.206	-.053	-.103	0.261	0.100	0.198	0.036
18. Total Evaluation Hours		1.000	-.038	0.590	0.322	-.105	0.494	0.266
19. Average Hours/Rejected Element			1.000	-.148	-.096	-.204	0.027	0.401
20. Average Hours/Accepted Element				1.000	-.056	-.017	0.090	0.080
21. Change in Image State Index					1.000	0.081	0.464	0.281
22. Contribution to Result						1.000	-.122	-.092
23. Total Integration Hours							1.000	0.759
24. Average/Accepted Element								1.000

APPENDIX K-3

Correlation Matrix of Independent and Dependent Variables

	VARIABLE MEASURES							
	Independent							
Dependent	1	2	3	4	5	6	7	8
1. Total Sources	0.045	0.115	-.134	0.188	-.237	-.224	-.200	-.028
2. Internal Sources	-.115	0.133	-.023	0.090	-.349	-.342	-.218	-.139
3. External Sources	0.261	0.011	-.217	0.212	0.092	0.106	-.040	0.161
4. Total Search Hours	-.236	0.209	0.063	-.077	-.256	-.261	-.118	-.056
5. Average Hours/Source	-.266	0.088	0.056	-.144	-.130	-.145	-.014	-.065
6. Number of Elements	-.273	-.056	0.203	-.134	-.198	-.073	-.277	-.097
7. Number "Rejected"	-.164	0.153	0.127	-.046	-.199	-.127	-.193	-.006
8. Number "Accepted"	-.223	-.277	0.173	-.160	-.072	0.031	-.195	-.154
9. Competency/Reliability - Total	0.082	-.231	-.307	0.332	0.055	-.035	0.166	0.042
10. Competency/Reliability - Rejected	-.065	-.168	-.176	0.224	0.123	0.034	0.257	0.117
11. Competency/Reliability - Accepted	0.203	-.051	-.131	0.178	0.079	0.013	0.138	-.041
12. Relevance - Total	0.457	0.058	-.241	0.243	-.277	-.296	-.196	-.081
13. Relevance - Rejected	0.259	0.060	0.088	-.047	-.116	-.197	0.041	-.016
14. Relevance - Accepted	0.304	0.236	-.044	0.068	-.322	-.459	-.018	-.266
15. Image State Conflict - Total	-.088	0.156	-.106	0.109	-.425	-.258	-.502	-.100
16. Image State Conflict - Rejected	-.057	0.157	-.098	0.107	-.342	-.271	-.283	-.023
17. Image State Conflict - Accepted	-.056	0.069	0.058	-.032	-.238	-.018	-.487	-.048
18. Total Evaluation Hours	-.209	-.085	-.122	0.149	-.170	-.039	-.301	0.004
19. Average Hours/Rejected Element	-.016	0.060	0.243	-.254	0.200	0.062	0.391	0.264
20. Average Hours/Accepted Element	0.135	0.056	-.236	0.166	-.054	0.009	-.196	0.019
21. Change in Image State Index	-.171	-.097	0.378	-.237	-.185	-.134	-.175	-.296
22. Contribution to Result	0.212	0.166	-.112	0.150	-.385	-.368	-.263	-.346
23. Total Integration Hours	0.033	-.160	-.029	0.101	-.229	-.175	-.212	-.008
24. Average/Accepted Element	0.107	-.107	0.096	-.066	-.095	-.180	0.101	0.100

APPENDIX K-3 (Continued)

	VARIABLE MEASURES							
Dependent	Independent							
	9	10	11	12	13	14	15	16
1. Total Sources	-.473	0.385	0.261	0.132	-.011	0.315	0.528	0.289
2. Internal Sources	-.360	0.415	0.191	0.200	-.150	0.296	0.316	0.370
3. External Sources	-.331	0.082	0.195	-.061	0.209	0.136	0.504	-.028
4. Total Search Hours	-.122	0.380	0.122	0.372	0.157	0.312	0.077	0.177
5. Average Hours/Source	0.150	0.130	-.026	0.413	0.065	0.164	-.149	0.028
6. Number of Elements	-.017	-.061	0.108	0.232	0.064	0.408	-.112	0.163
7. Number "Rejected"	-.209	0.108	0.247	0.200	0.161	0.167	-.043	0.241
8. Number "Accepted"	0.242	-.226	-.130	0.101	-.108	0.443	-.131	-.037
9. Competency/Reliability - Total	0.436	-.058	-.395	-.097	-.282	-.146	0.075	-.303
10. Competency/Reliability - Rejected	0.303	0.165	-.244	-.060	-.272	-.135	-.045	0.157
11. Competency/Reliability - Accepted	0.434	0.002	-.184	-.170	-.194	-.253	-.134	-.216
12. Relevance - Total	-.048	-.380	-.386	-.039	0.148	-.164	0.057	-.242
13. Relevance - Rejected	0.015	-.065	-.329	-.335	0.018	-.083	-.141	0.192
14. Relevance - Accepted	0.153	-.349	-.128	0.050	0.061	-.204	-.171	-.052
15. Image State Conflict - Total	-.486	-.025	-.012	0.196	0.325	0.160	0.125	0.110
16. Image State Conflict - Rejected	-.392	-.007	-.062	0.194	0.179	-.017	0.028	0.094
17. Image State Conflict - Accepted	-.459	0.097	0.147	0.087	0.369	0.291	0.076	0.261
18. Total Evaluation Hours	-.324	0.157	0.180	0.172	0.084	0.395	0.518	0.322
19. Average Hours/Rejected Element	-.044	0.268	0.021	0.153	-.135	-.132	0.107	-.096
20. Average Hours/Accepted Element	-.281	-.072	0.098	-.091	0.206	0.038	0.460	-.056
21. Change in Image State Index	-.047	-.142	0.244	-.111	-.167	0.360	-.051	1.000
22. Contribution to Result	0.155	-.391	-.152	0.092	0.138	-.129	-.226	0.081
23. Total Integration Hours	-.110	0.036	0.091	0.079	-.161	0.384	0.337	0.464
24. Average/Accepted Element	-.083	0.056	0.265	0.080	-.010	0.190	0.179	0.280

APPENDIX K-3 (Continued)

VARIABLE MEASURES			
Dependent	Independent		
	17	18	19
1. Total Sources	-.162	0.019	-.095
2. Internal Sources	-.191	0.010	-.073
3. External Sources	-.010	0.021	-.067
4. Total Search Hours	-.032	-.014	-.181
5. Average Hours/Source	0.120	-.037	-.177
6. Number of Elements	0.090	-.051	-.004
7. Number "Rejected"	-.085	-.040	0.124
8. Number "Accepted"	0.248	-.030	-.167
9. Competency/Reliability - Total	0.481	0.171	-.014
10. Competency/Reliability - Rejected	0.081	0.126	0.060
11. Competency/Reliability - Accepted	0.410	0.050	-.065
12. Relevance - Total	0.002	-.227	-.149
13. Relevance - Rejected	-.220	-.139	-.093
14. Relevance - Accepted	-.063	-.192	-.106
15. Image State Conflict - Total	-.349	-.145	-.101
16. Image State Conflict - Rejected	-.390	-.079	-.023
17. Image State Conflict - Accepted	-.300	-.189	-.102
18. Total Evaluation Hours	0.142	0.117	0.002
19. Average Hours/Rejected Element	-.192	0.563	0.122
20. Average Hours/Accepted Element	0.144	-.087	-.068
21. Change in Image State Index	-.172	-.295	-.083
22. Contribution to Result	-.073	-.289	-.051
23. Total Integration Hours	0.103	-.021	-.186
24. Average/Accepted Element	-.020	0.077	-.170

APPENDIX L

CANONICAL ROOTS

Root Number	Canonical Root[1]	Chi Square	Degrees of Freedom	Rejection Probability
1	.8825	56.745	25	.001
2	.7524	36.994	23	.035
3	.7070	32.533	21	.054
4	.7027	32.148	19	.032
5	.5945	23.920	17	.124
6	.4239	14.615	15	.519
7	.3490	11.377	13	.580
8	.2223	6.663	11	.826
9	.1793	5.236	9	.814
10	.1279	3.628	7	.822
11	.1133	3.186	5	.674
12	.0529	1.441	3	.700
13	.0180	0.482	1	.505

[1]The canonical correlation coefficient is equal to the square root of the canonical root.

APPENDIX M-1

ELIMINATION OF VARIABLE MEASURES

Certain variable measures were included in the study which by definition were not independent of each other. Another source of overlapping measurement was that of using more than one instrument to measure a particular variable. While these measures are independent and may not measure entirely the same characteristic (such as intellective aptitude) inclusion of more than one measure would tend to suggest a stronger relationship through canonical analysis than may actually be present. Thus, the dangers of inclusion seemed greater in certain cases, than those of exclusion.

These non-independent and overlapping measures were included in order to obtain the most promising set for analysis. If all were included in the canonical analysis of the data there would be a tendency to end up with canonical correlation coefficients much higher than might actually be present. Of course, there can be similar dangers in leaving out measures that contribute to the relationships. The measures eliminated represent an attempt to eliminate only those where inclusion might tend to overstate an apparent relationship and whose exclusion did not appear to leave out any meaningful degree of explanation.

Six independent variable measures were not analyzed beyond the simple correlations shown in Appendix K. The specific factors leading to the exclusion of these measures in the canonical analysis are indicated below.

Since ARAC experience (1) is a component of total professional experience (2), the inclusion of both measures would tend to distort

a
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upward the observed relationship between the independent and dependent variable sets.* ARAC experience was used in the analysis based on a comparison of the correlations in Appendix K.

Performance rank (3) and performance index (4) are overlapping measures of job performance. Based on the nature of the measurement and simple correlations with each of the dependent measures, the performance index measure was selected for the analysis.

The ATGSB (5, 6, and 7) and Wonderlic (8) measures both seek to measure intellective aptitude. Although they are not completely similar they appear to overlap considerably. In view of this, the Wonderlic score was selected as the measure of intellective aptitude for analysis of the data. Another factor in favor of this choice was that ATGSB scores were not available on three of the subjects. It is important to note that such an exclusion runs the risk of not including an explanatory influence not contained in the second measure.

The man-hours invested (14) and rating (13) measures of task scope and complexity seek to measure the same variable. The man-hours measure was eliminated for two reasons. First, the rating measure, using simple correlations as a guide, seemed to be the best of the two. Secondly, the man-hours invested measure is highly correlated with the dependent measures of search, evaluation, and integration investment which, by definition, should be expected.

Eleven dependent variable measures were not included in the canonical analysis of data. The reasons for excluding these measures are indicated below.

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*The numbers in parentheses refer to the variable measures as listed in Appendix M-2.

Total sources sought (1), total search hours (4), number of information elements processed (6), competency and reliability—mean rating of total elements processed (9), relevance to task-mean rating of total elements (12), image state conflict—mean rating of total elements (15), evaluation investment (average hours/rejected element (19) and average hours/accepted element (20)), and integration investment in total hours (23) were eliminated because they were by definition not independent of other measures which were retained in the analysis.

The measure used for the change in image state index (21) was by definition the difference between the image state at the outset of the task (an independent variable) and the image state at the completion of the task. If the image state at the end of the task is assumed to be perfect (zero), then the image state change is equal to the value at the outset of the task. This resulted in both the independent and dependent variable measures being equal. Accordingly, the dependent measure, image state change was excluded from the analysis.

Conceptually, relevance to task (13 and 14) and contribution to result (22) were intended to measure different things. However, contact with the subjects during the study indicated that they could not, in fact, distinguish between the two. The correlation between relevance of accepted elements (14) and contribution to result of accepted elements (22) was 0.781 as indicated in Appendix K. For these reasons the contribution to result measure was not included in the canonical analysis of the data.

The basic data collected in the study are shown in Appendix J.

APPENDIX M-2

Variables and Measures Used in Investigating Relationships
(Measures Used in Canonical Analysis are Underlined)

VARIABLES	MEASURES USED
INDEPENDENT SET	
INDIVIDUAL	
P_1 - Experience	1. ARAC Experience
	2. Total Experience (Professional)
P_2 - Job Performance	3. Performance Rank
	4. Performance Index
P_3 - Intellective Aptitude	5. ATGSB Total Score
	6. ATGSB Verbal Score
	7. ATGSB Quantitative Score
	8. Wonderlic Score
P_4 - Risk-Taking Propensity	9. RTP Index
P_5 - Information-Processing Efficiency	10. IPE Index
TASK*	
T_4 - Time Span	11. Days
T_5 - Precision of Definition	12. Rating
T_6 - Scope and Complexity	13. Rating
	14. Technical Man-hours Invested
T_7 - Result	15. Rating
INDIVIDUAL/TASK (Joint)	
J_1 - Image State for Task	16. Image State Index
J_2 - Interest in Task	17. Interest Rating
J_3 - Uncertainty of Outcome	18. Probability Estimate (Outcome)
J_4 - Ordinal Position of Task	19. Rank of Task

*Relationships for variables T_1, T_2, and T_3 were not investigated. For further discussion see Chapter 4. Variables T_2 and T_3 were constant for the 40 tasks included in the study.

APPENDIX M-2 (Continued)

VARIABLES	MEASURES USED
DEPENDENT SET	
SEARCH PHASE	
I_1 - Sources Sought	1. Total Sources 2. Internal Sources 3. External Sources
I_2 - Search Investment	4. Total Search Hours 5. Average Hours/Source
RECEIPT PHASE*	
EVALUATION PHASE	
(These measures were included for control purposes)	6. Number of Elements 7. Number Rejected 8. Number Accepted
I_6 - Competency/Reliability	9. Mean Rating - Total Elements 10. Mean Rating - Rejected Elements 11. Mean Rating - Accepted Elements
I_7 - Relevance to Task	12. Mean Rating - Total Elements 13. Mean Rating - Rejected Elements 14. Mean Rating - Accepted Elements
I_8 - Image State Conflict	15. Mean Rating - Total Elements 16. Mean Rating - Rejected Elements 17. Mean Rating - Accepted Elements
I_9 - Evaluation Investment	18. Total Evaluation Hours 19. Average Hours/Rejected Element 20. Average Hours/Accepted Element
INTEGRATION PHASE	
I_{10} - Image State Change	21. Change in Image State Index
I_{11} - Contribution to Result	22. Mean Rating - Accepted Elements
I_{12} - Integration Investment	23. Total Integration Hours 24. Average/Accepted Element

*As explained in Chapter 4, variables I_3, I_4, and I_5 were not included in the study.

APPENDIX N

Canonical Weights for Measures in the 3 x 13 System of Variables

Variable Measures	Canonical Weight
INDEPENDENT SET	
Information-Processing Efficiency Index	.7413
Image State Index	.5781
Result Rating	.3411
DEPENDENT SET	
Sources Sought (Internal)	.5507
Sources Sought (External)	.2239
Search Investment (Hours/Source)	.1840
Rejected Elements Processed	-.0382
Accepted Elements Processed	-.3543
Competency/Reliability (Rejected Elements)	.2960
Competency/Reliability (Accepted Elements)	-.1162
Relevance to Task (Rejected Elements)	.0386
Relevance to Task (Accepted Elements)	-.2798
Image State Conflict (Rejected Elements)	-.4410
Image State Conflict (Accepted Elements)	.3189
Evaluation Investment (Hours)	.0041
Integration Investment (Hours)	.0933

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